A Natural Capital Account for the Tees Valley

An exploration of natural capital accounting for County and City Regions

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A Natural Capital Account for the Tees Valley: An exploration of natural capital accounting for County and City Regions

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Further information

This report can be downloaded from the Natural England Access to Evidence Catalogue: http://publications.naturalengland.org.uk/. For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Executive summary

Introduction

This report is a natural capital account for the Tees Valley. It follows the innovative approach to natural capital accounting we developed for our National Nature Reserves (NNRs). We have built on our ground-breaking Natural Capital Indicators as well as the mapping of the indicators in National and City/County scale Natural Capital Atlases. The report explores the extent to which it is possible to develop an approach that can be replicated across other areas and how local planning can be informed by natural capital accounts and Natural Capital Atlases.

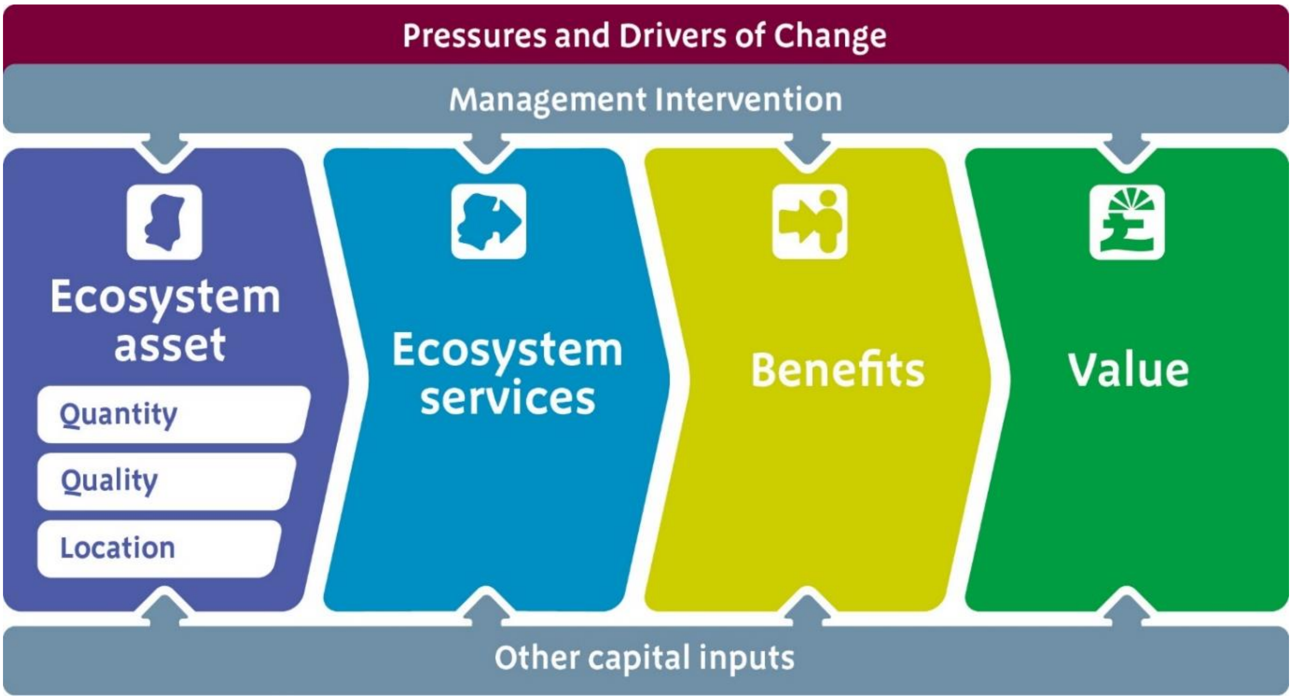
Natural capital

The natural environment provides a wide range of benefits to people. These include food, water, flood alleviation, thriving wildlife and places to enjoy. The Natural Capital Committee (NCC) has defined natural capital as “the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions”.

Logic chains to aid the understanding of natural capital

A natural capital approach sees the natural environment as a stock of assets. These assets enable a flow of ecosystem services to people, who benefit from them, and therefore value them. Figure 1, below, shows this flow of services from natural capital assets to people as well as illustrating the factors which influence this flow of services.

Figure 1 Natural Capital Logic Chain



Natural Capital Accounts

Natural capital accounts are a way of organising information about natural capital to inform decision making. They extend traditional accounts by putting economic values on benefits that are not provided through the market. In time they may perform a similar role to traditional accounts by becoming part of an organisation's external accountability and supporting internal decision-making. They also have an important role in communicating environmental benefits and the state of natural assets.

Our natural capital accounting method

We have developed an extended balance sheet to report on the quantity and quality of the assets, the ecosystem services, benefits and values alongside each other. Asset quality has been estimated using indicators mapped in our Natural Capital Atlases wherever possible. Our Natural Capital Atlases use natural capital indicators to explore the distribution and condition of natural assets both nationally and at County/City scale. Data sets have been used that describe aspects of hydrology, soils, nutrient and chemical status, vegetation, species composition and cultural benefits, as recommended in Natural England's Natural Capital Indicators Report.

Benefits and values have been estimated using only publicly available, national datasets. Where quantified data is missing, we have estimated the significance of ecosystem service provision and benefits qualitatively using the expert judgement of a small number of Tees Valley stakeholders. Definitions of significance ratings are shown in Table 1 below. We did this to reduce the risk of partial valuation being misinterpreted, for example incorrectly assuming that ecosystem services or benefits we could not quantify are insignificant, and to present a more complete picture to decision-makers.

Table 1 Significance ratings

Significance	The ecosystem service provides socioeconomic benefits that are…	
0	None	Very low/minor or absent
1	Low	Relatively low across the selected area
2	Medium	'Medium' across the selected area
3	High	High across the selected area

To provide further transparency we use confidence levels (shown as a Red – Amber – Green traffic light rating) to indicate the quality and appropriateness of the information behind the value figures, as shown in Table 2.

Table 2 Key to confidence intervals

Definition	Colour
We may have used some assumptions or estimation but consider these figures uncontroversial.	Green
We have used some assumptions or estimation and some of these may be open to question. Accuracy is better than + or -50%.	Amber
We are confident that the number is in the right order of magnitude. Order of magnitude implies that for an estimate of 5 that we are confident that the real figure is within the range 0.5 to 50.	Red
We can't offer a number which is likely to be in the right order of magnitude.	No number

Tees Valley

This Account covers all natural capital, regardless of ownership, within the boundary covered by the Tees Valley Combined Authority (TVCA). The Tees Valley is an urban area in the North-East region of England consisting of five unitary authorities: Darlington, Hartlepool, Middlesbrough, Redcar and Cleveland and Stockton-on-Tees. The region covers a population of approximately 650,000 people.

The TVCA describes the natural capital of Tees Valley as “a unique mix of natural assets, which have shaped the development and growth of our area for generations. These include: RSPB Saltholme; Roseberry Topping; Saltburn (surfing); Tees Barrage; Greatham Creek (seal watching); as well as various parks and Nature Reserves. The River Tees and expansive coastlines are also defining features in the region, providing the backdrop for significant industrial, community and visitor sites.”

The Tees Valley extends over 75,000 hectares (ha), of which about 75% of this land is not covered by urban areas[1]. Broad habitat types have been estimated and mapped using 2015 Land Cover Maps produced by the Centre for Ecology and Hydrology (CEH), as shown in Table 3 and Figure 2.

Table 3 Habitat extent by National Ecosystem Assessment (NEA) Broad Habitats across Tees Valley

National Ecosystem Assessment Broad Habitat (NEA-BH)	Area across Tees Valley (ha)	% of Total
Enclosed farmland	44,461	59
Urban	20,597	27
Woodlands	4,789	6
Marine	2,013	3
Semi-natural grassland	1,409	2
Coastal margins	859	1
Open water, wetlands and floodplains	731	1
Mountains, moorlands, heaths	260	0
Total	**75,119**	**100**

The LCM2015 dataset only covers a limited proportion of the UK marine area. Alternatively, the Tees Valley Natural Capital Atlas maps marine habitats up to 12 nautical

[1] In Table 3 and Figure 2, ‘Urban’ includes the whole area classified as urban by the LCM 2015 dataset. This will include urban habitats such as parks and gardens, as well as general urban areas, such as roads, houses, and other infrastructure. Actual amounts of Urban habitats have not been calculated in this account.

miles from the coastline. Using this definition, the extent of marine habitat is much more extensive than shown in Table 3, about 72,500 ha.

As shown in Table 3, above, the main land cover types are enclosed farmland (44,500 ha), urban (20,600 ha) and woodland (4,800 ha). Figure 2, below, shows how these broad habitats are distributed across the Tees Valley. Urban areas are particularly focused around the Tees Estuary and River Tees. Enclosed farmland is spread across the rest of the Tees Valley. Woodland is particularly predominant to the east of the Tees Valley in Redcar and Cleveland. Although only covering a small total area, there is an important area of mountains, moorlands and heaths found in the south east where the North York Moors crosses the boundary of Redcar and Cleveland.

Figure 2 Map of the Tees Valley by broad habitat

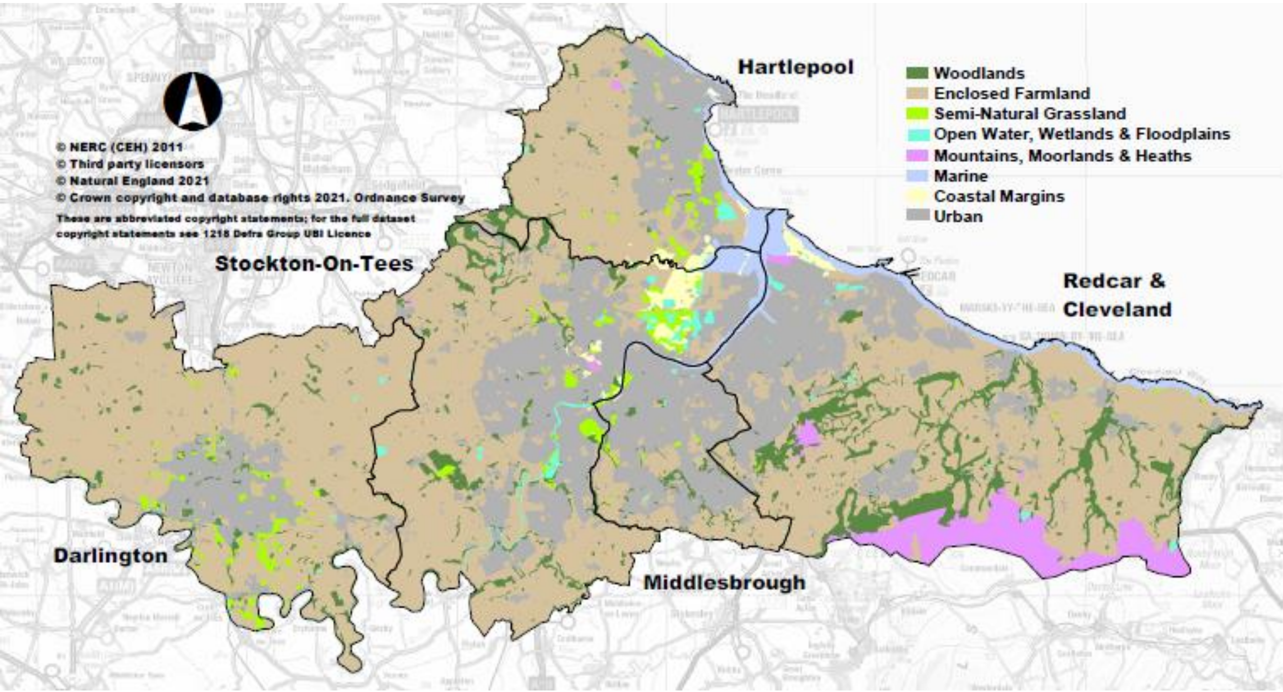


Table 4 Headline results

Ecosystem asset

Natural capital asset baseline		
Asset Attribute	**Indicator**	**Value**
Extent	Total area (ha)	75,000
Hydrology	Ground water quantity status (% good) Water Framework Directive (WFD)	69%
	Hydrological status (% good) WFD	19%
	Bathing water quality (% good)	100%
Nutrient/ Chemical status	Surface water quality status (% good) WFD	37%
Soil/ sediment processes	Mean Estimates of Soil Organic Carbon in Topsoil, 0-15cm depth (tonnes per ha)	52.7
	Soil invertebrate abundance, mean estimates of total abundance in topsoil (0–8cm depth soil core)	40.0
Species Composition		
Vegetation	Nectar plant diversity, mean estimates of number of nectar plant species for bees (per 2×2m plot)	4.2
Cultural	% area of Sites of Special Scientific Interest in favourable condition	51%
	Public rights of way (km/ha)	0.012
	Area of designated historic environment assets (ha)	535
	Scheduled monuments at risk (ha)	148

Ecosystem services

Ecosystem service (common name)	**Indicator**	**Quantity** where available
Timber and other materials	Sales of wood and wood products (tonnes/year)	
Fish, marine products & game	Fish and marine products landed (tonnes)	1,500
Livestock	*Number of cattle, sheep and pigs*	*130,000*
Crops	*Cropped area (ha)*	*21,000*
Water supply	Quantity abstracted for public water supply	
Clean water		
Clean air	*Annual mean concentration of $PM_{2.5}$ at AURN network monitors ($\mu g/m^3$)*	*7-10*
Pollution regulation	PM2.5 removed by woodland (tonnes/year)	28
Erosion control		
Flood protection		
Pollination		
Pest and disease control		
Thriving wildlife		
Climate regulation	Carbon sequestration, t CO_2 equiv/yr Emission (arable & horticulture) Sequestration (other habitats)	(~157,000) ~84,000
Cultural - Experiential and physical use	Number of recreational visits (million/year)	25
Cultural appreciation of nature		
Cultural - Scientific and educational use		

Notes:
Gaps are shown as greyed out boxes where data was not available to measure an attribute.
Indicators in *italics* are best available proxies for services. Values in red are negative
Significance ratings based on exploratory exercise conducted with a small group of Tees Valley stakeholders.
Confidence in values: Red is low, Amber is medium, Green is high

Benefits and values

Benefit	Significance (1 small to 3 large)	Indicator	Annual benefit	Asset value	Confidence in the values
Timber, hay and other materials	1	Timber and wood products, stumpage value			
Food	1	Net income from fisheries	£360,000	£11 million	
	1	Resource rent from crop and livestock production	~ £0	~ £0	
Clean and plentiful water	3	Value of water abstraction			
Clean air	3	Health benefits from PM2.5 removal	£8 million	£235 million	
Protection from floods and other hazards	3	Value of flood protection benefits provided by natural capital			
Pollination and pest control	1	Value of pollination and pest and disease control			
Biodiversity	2				
Equable climate	3	Social cost of carbon emission (natural capital)	(£5 million)	(£395 million)	
Cultural wellbeing	3	Social benefit of recreational visits (parks, beaches & paths)	£100 million	£3.0 billion	
	3	Physical and mental health and other benefits			
Total quantified monetary benefits			**£103 million**	**£2.8 billion**	
Significance of unquantified monetary benefits			**Very large**		

Asset quality

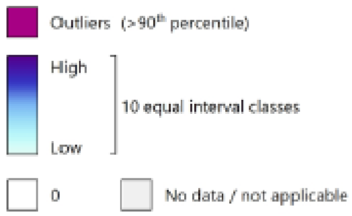
Asset quality is described, on the left-hand side of the extended balance sheet (Table 4, above), using the approach developed for National Nature Reserves. Asset quality indicators have been chosen as a set of indicators that represent the state of the environment across a range of functions (e.g. hydrology, species composition), using nationally available and accessible data. Where possible these are based on the indicators mapped in the City/County Natural Capital Atlases. Atlas indicators have been supplemented with additional publicly available datasets where necessary.

The asset quality indicators included in the extended balance sheet provide both an indication of the ecological quality of natural capital assets in the Tees Valley and a baseline assessment against which changes in quality and extent of the natural capital assets could potentially be measured at a future date, where data are appropriate for doing so. Figure 3, below, shows examples of the Tees Valley maps for soil biota, Public Rights of Way and natural aquifer function. The maps show how the Tees Valley compares with the rest of the country and how the extent and condition of natural assets varies across the Tees Valley.

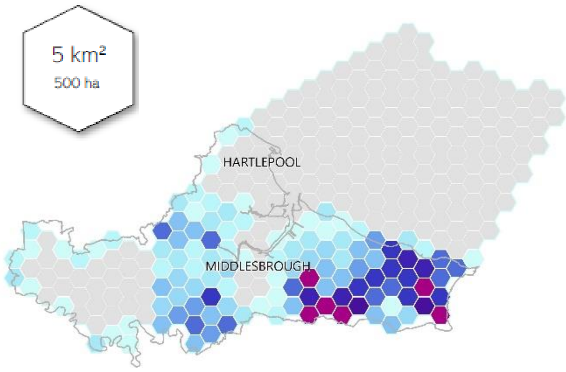
Figure 3 Asset quality indicators – Examples from the Tees Valley Natural Capital Atlas

Map Key

Indicator value:

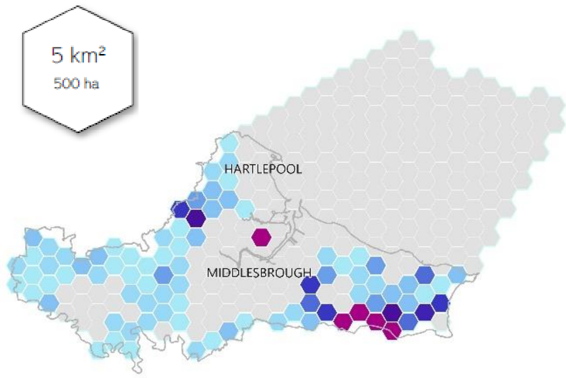


Public Rights of Way



Hexagon values: 0 – 13.61 km; Outliers 13.61 – 46.31 km

Soil Biota



Hexagon values: 11 – 80; Outliers 80-183

Natural Aquifer Function

Groundwater status: Good Poor

Services

The ecosystem assets of the Tees Valley deliver a wide range of ecosystem services. Provisioning services include production of timber and wood products, fish and marine products harvested from the sea, crop and livestock production and provision of fresh water. Regulating services include climate regulation, water quality, flood protection and improvement of air quality via removal of particulates by vegetation. Cultural services include experiential, physical use, scientific and educational use and cultural appreciation of nature.

The quantity, quality and location of assets influence this ecosystem service delivery, as does management and external pressures. We can quantify only a proportion of these ecosystem services. Where we can quantify the ecosystem services we do so based on a combination of evidence and assumptions. For example, the number of recreational visits is based on a tool that predicts visits using a national data set, rather than detailed local measurements. Similarly, there is no public data set that provides an overview of crop or timber production at Local Authority level, so we have used indicators of asset quantity as a proxy for the ecosystem service for some services, for example cropped area rather than crop production.

Additionally, there are many important ecosystem services which we are unable to quantify. To give one example, land maintained as woodland can hold and slow down water, potentially reducing flooding downstream, but there is no national data set or tool that would enable us to estimate the scale of this effect for the Tees Valley without detailed modelling. Despite their importance, services that are often omitted from natural capital accounts are regulating and cultural services such as flood mitigation, thriving wildlife and natural beauty.

Value and Significance of Benefits

Society values natural capital for the enjoyment people gain from the benefits it provides. Where possible we have estimated their monetary value. Where quantified data is missing, we have estimated the significance of ecosystem service provision and benefits qualitatively using the judgement of local stakeholders. We did this to reduce the risk of partial valuation being misinterpreted and to present a more complete picture to decision-makers.

Overall, we estimate the monetary value of quantifiable benefits from natural capital in the Tees Valley to be in excess of £100 million per year with a natural capital asset value of around £3 billion. As explained above, there are benefits of 'very large' significance that we have not been able to value in monetary terms and suggest that, based on the level of significance placed on these non-monetised benefits, these are likely greater than the quantified values.

The majority of benefits which we could value were from recreation, which were estimated as being of the order of £100 million per year. The next most significant were the health benefits associated with improved air quality, at about £8 million per year. We also estimate small benefits associated with fisheries, crops and livestock.

Additionally, we quantify the contribution natural capital assets make to sequestering carbon. Focussing only on those habitats that sequester carbon, we estimate a benefit of about £5.7 million. However, these benefits are outweighed by the emissions from arable and horticultural habitats. Overall, we estimate that net carbon emissions from natural capital assets in the Tees Valley have an annual social cost of around £5 million. The unit cost of carbon emissions represents the cost of other measures to remove the equivalent amount of carbon at that point in time. It is therefore scheduled to rise sharply over the next 50 years. If emissions remain at current levels the annual cost of these emissions would reach £26 million in 2075.

Benefits that we cannot value in monetary terms provide large additional benefits and some are highly significant. Those identified as most significant were water abstraction, flood protection, biodiversity, and physical and mental health. Other non-monetised benefits include timber, pollination services and other cultural benefits that people gain from nature, such as scientific and educational opportunities and cultural appreciation. The £103 million per year figure represents only those services that can be valued in monetary terms, not those that are most important. It is therefore a significant under-estimate of the true value of natural capital across the Tees Valley.

Discussion and Conclusions

The results show the importance of natural capital in the Tees Valley, delivering annual benefits in excess of £100 million through recreation opportunities, improved air quality, thriving wildlife, water supply and flood mitigation. The significance that local stakeholders placed on benefits we could not monetise, shows the partiality of our value and that non-monetised benefits are likely greater than those we have quantified.

The presentation of information on assets, services, benefits and values together seeks to avoid this problem of partial accounts that occurs in natural capital accounting. We believe this approach is appropriate to inform strategic decision-making about natural capital assets. It is particularly appropriate for organisations who are concerned about the state of natural assets and the long-term provision of public goods. It is therefore particularly relevant to public bodies and charities, but also private sector organisations with a commitment to corporate responsibility.

Building the accounts on key attributes of the natural capital stock itself, enables us to understand how the state of our natural capital is changing, and can act as an early warning system for future changes in the provision of ecosystem services, benefits and values. This can be particularly useful when repeated over time such that changes are identified. This account, together with the Tees Valley Natural Capital Atlas provide an extensive baseline against which future assessments, of ecological asset quality, ecosystem service delivery and benefits, can be compared.

Where possible we include a comparison of the Tees Valley asset quality indicators with national estimates to provide context for the figures. However, we have not explored why differences exist, so we do not comment on whether the assets are in good condition or otherwise. Nonetheless, this information combined with the national and Tees Valley Natural Capital Atlases, which both provide mapped representations that help demonstrate how natural capital across the Tees Valley compares with other areas, provide a good starting point for further consideration of this.

The Account provides evidence on total benefits across the Tees Valley. It does not assess how they vary within the region. Using the Account alongside the Tees Valley Natural Capital Atlas, provides not only estimates of overall quality and value of natural assets but also a representation of the distribution and condition of natural capital assets across the area.

Our approach was exploratory, with the objective of using Natural Capital Atlas indicators and supplementing this only with publicly available data and methodologies that could be used and replicated in other areas. This approach has shown the difficulty of producing an account in this way, with a limited number of relevant, spatially disaggregated, national datasets and models for services and benefits. There are huge opportunities for further data collection and modelling to fill gaps and improve the Tees Valley account, such as around timber production, flood mitigation and water supply. However, the complexity of the environment means that natural capital accounts will always be partial and it is important that this is recognised. A further improvement would be to incorporate costs of maintaining natural capital and how these are distributed across different sectors.

As noted above, this Account provides a baseline against which future assessments could be compared. However, most of the datasets used are not updated on an annual basis. This suggests that annual accounts would not be appropriate as they will not pick up on change. A more useful objective would be to increase the extent of services that have been estimated and valued, as recommended above, before considering whether to repeat the study.

Contents

1 Introduction

1.1 Purpose of this report

This report is a natural capital account for the Tees Valley. The Account follows our innovative approach to natural capital accounting we developed for our National Nature Reserves (NNRs) (Sunderland et al. 2019). We have built on our ground-breaking Natural Capital Indicators (Lusardi et al. 2018) as well as the mapping of the indicators in National (Wigley et al. 2020) and City/County scale (Lear et al. 2020) Natural Capital Atlases. The report explores the extent to which it is possible to develop an approach that can be replicated across other County or City Regions and how local planning can be informed by natural capital accounts and Natural Capital Atlases.

The Tees Valley Combined Authority (TVCA) describes the natural capital of Tees Valley as “a unique mix of natural assets, which have shaped the development and growth of our area for generations. These include: RSPB Saltholme; Roseberry Topping; Saltburn (surfing); Tees Barrage; Greatham Creek (seal watching); as well as various parks and Nature Reserves. The River Tees and expansive coastlines are also defining features in the region, providing the backdrop for significant industrial, community and visitor sites” (TVCA, 2016). The Account covers all natural capital within the Tees Valley, regardless of who owns or manages it and whether or not it is accessible to the public.

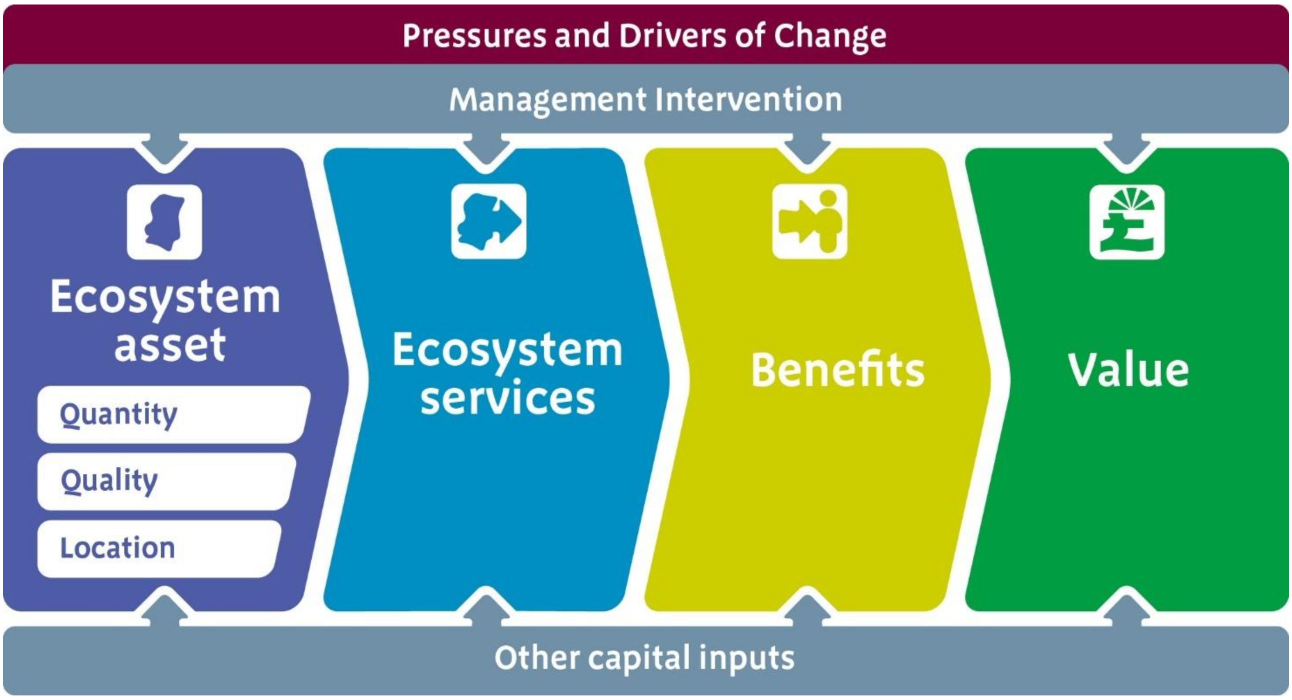
Traditional accounting allows organisations to keep track of their assets. It provides information on asset value, state and maintenance costs. But it only includes benefits which are traded in markets. Many benefits provided by the natural environment are provided for free, outside the market, and so are not captured. As a result, these benefits are often undervalued, or ignored altogether, in decision-making. Natural capital accounting extends accounting to non-market benefits, such as carbon sequestration or recreational values. These broader based accounts can inform and improve an organisation’s decision-making.

1.2 Our approach to natural capital

The Natural Capital Committee (NCC) has defined natural capital as: “the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions” (Natural Capital Committee 2017). The concept of natural capital is broad and covers both living and non-living parts of the natural world as well as the processes that link these and sustain life on Earth, including humans.

Natural capital considers our natural environment as a stock of assets that enable a flow of ecosystem services to people who benefit from them and therefore value them. These include food, water, flood protection, thriving wildlife and places to enjoy. This flow of services from natural capital assets to people is represented in Figure 4 below.

Figure 4 Natural Capital Logic Chain

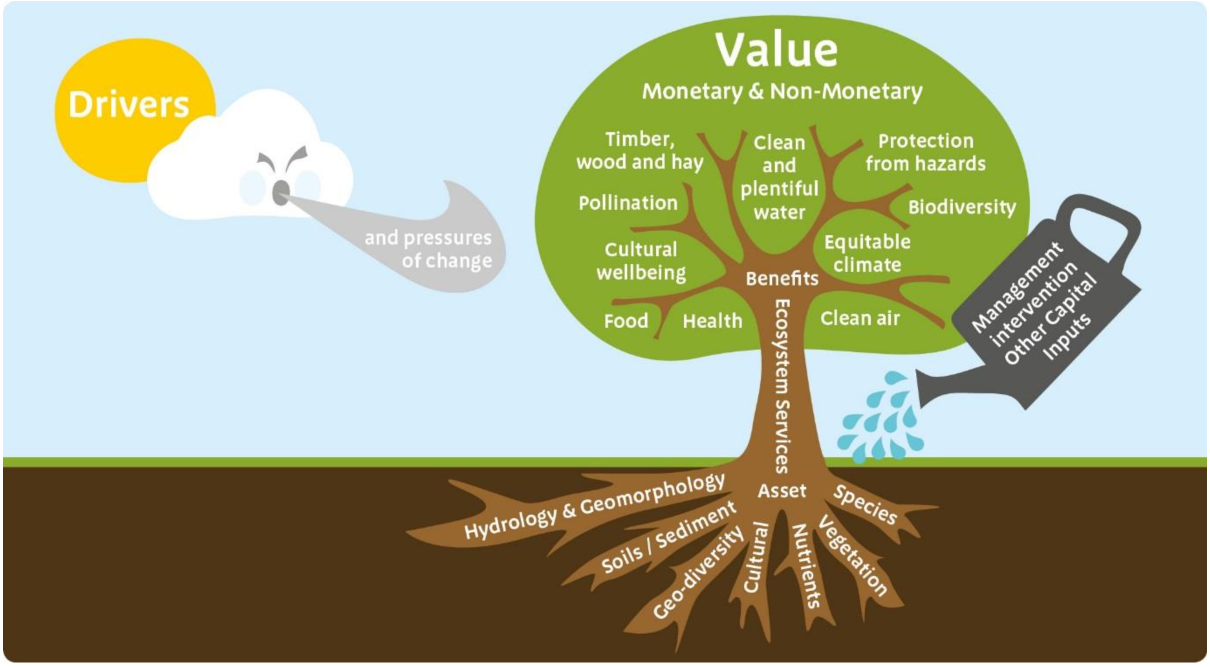


An example of this flow might be farmland (asset) that provides a crop (ecosystem service) that is turned into food (benefit) that people value and buy. Critically, it is not only the quantity of the asset that influences the potential flow of ecosystem services, but also the quality of the assets and where they are in relation to people. Our diagram also recognises that these logic chains exist in context and are influenced by management and wider pressures and drivers of change. Finally, most of the final benefits received by people are as a result of a mixture of natural capital and other capitals. For example, the production of crops requires an input from nature, but also one from labour and machinery. Even recreation requires car parks or walking routes.

This 'logic chain' is a simplistic representation of a system that in reality is highly complex and multi-dimensional. Often multiple assets are contributing to ecosystem services and similarly multiple services may be contributing to, or trading off, to provide benefits and values. However, this simplified approach helps us to tease out some of these relationships in a systematic way and to identify important attributes of the assets, the consequential services, benefits and values. Natural England has used this natural capital logic chain as the basis for our natural capital accounts, seeking to report on each part of the chain.

This study is unusual in the percentage of our effort which has gone into understanding the ecological status of the assets. Although difficult, this work is essential, because it is the state of the asset which will control whether services continue to be delivered into the future. The tree diagram (Figure 5) features the same system as the logic chain, but inverts it so that ecological condition is shown as the roots of the system. The detail around the roots shows the ecological indicators we have used to assess quality.

Figure 5 Logic chain 'tree diagram' showing ecological components of asset state



1.3 Background

Natural capital accounts have been promoted by the Natural Capital Committee, which sees them as a central tool in mainstreaming the value of nature. As well as our NNR Accounts, natural capital accounts have been produced by organisations including Forest Enterprise, the Environment Agency and the National Trust, as well as covering a range of geographic locations, such as Greater Manchester, Greater London and Birmingham.

There are broadly two types of natural capital account; strategic and corporate. Strategic natural capital accounts look at natural capital value across a land area. For example, the Office for National Statistics (ONS) work across England (ONS 2019a), the accounts for national parks (Eftec et al 2015) and city-wide accounts (e.g. Dickie et al., 2018, Hölzinger and Grayson, 2019). In contrast a corporate approach looks at the land holdings of a specific organisation and is often more detailed. As this study is focused on a Combined Authority region we concentrate on a more strategic based approach.

1.4 Concerns about natural capital accounts that we have addressed

There are a number of significant concerns about natural capital accounts as a decision-making tool. We have addressed these in a similar manner to our NNR Accounts.

Natural capital accounts tend to report the final balance sheet as the result of the study. In other words, the financial values are upfront. If it was possible to capture all the costs and benefits in the balance sheet this would be appropriate. However, the reality is that there are many benefits that we can't quantify or value, but are important. Also, there is a consistent pattern to which benefits are easiest to put an economic value on. So natural capital accounts often place a value on crops, carbon sequestration and recreation, but rarely on thriving wildlife, natural beauty or flood protection. If the balance sheet is seen as the 'answer', decision-making will be skewed towards those that can be valued. In this study we have sought to avoid this problem by estimating the significance of benefits qualitatively as well, and drawing attention to these judgements in the summary results.

Communicating confidence levels in the results. Natural capital accounts have tended not to do this, but it's essential that they do. Without this decision-makers are likely to misinterpret the results, perhaps assuming that confidence levels are similar to those in traditional accounts. In this study we have avoided this problem by clearly marking our confidence levels on values and quantitative findings. Our confidence levels range from numbers we consider uncontroversial to numbers which could be ten times larger or smaller.

Losing sight of the natural assets themselves, and the state they are in. At the heart of the idea of natural capital is bringing natural assets into a management cycle, so that they are invested in, and maintained. We cannot do this unless we understand their condition. It is many times harder to do this for natural assets than it is for manufactured assets. Natural assets are systems we didn't design and don't fully understand. Also, it is possible to produce some economic values for benefits without really understanding how they relate to natural asset quality. For example, we can value recreation based on an average trip to woodland, but this tells us nothing about which qualities of woodlands are important for recreation. Similarly, we can produce asset values based on the assumption that benefits will continue at current levels, but the critical question is 'will they?' To get a handle on this we need to understand the underlying state of the assets. In this study we have used Natural England's Natural Capital indicators and Natural Capital Atlases to demonstrate this using available data.

1.5 Potential roles for natural capital accounts

Natural capital accounts are an emerging tool and it is not yet clear what decision-making purposes they will be able to serve. They do not have the status of external accounts, which are used to hold an organisation to account. It will be difficult for them to assume this role because it would require achieving a greater level of objectivity than is possible at the moment. Instead they could be used as management accounts – internal information to support better decision-making. If this is the case then the sorts of innovations we have used in the study will be an essential starting point. They would need to be complemented by a broader dashboard of targets. They also have a role in communicating the wider benefits offered by natural capital assets.

To explore further the potential use of natural capital accounts in decision-making we undertook a case study that looked at the role natural capital accounts could play in improving project planning, with a specific focus on the delivery of net zero carbon objectives.

2 Methodology

This section describes the methodology we have undertaken to produce this account. An objective of this report was to explore the extent to which a natural capital account could be produced for a County or City Region using a Natural Capital Atlas. It was therefore crucial that any data and methodologies were replicable in other areas, such that a similar account could be produced for another Atlas area. Therefore, any datasets or tools we used had to be publicly available and cover the whole of England. Additionally, methodologies relied on existing data and studies.

2.1 Natural Capital Assets

2.1.1 Which assets are included in the account?

This Account covers all natural capital, regardless of ownership, within the boundary covered by the Tees Valley Combined Authority (TVCA). The Tees Valley is an urban area in the North-East region of England consisting of five unitary authorities: Darlington, Hartlepool, Middlesbrough, Redcar and Cleveland and Stockton-on-Tees. The region covers a population of approximately 650,000 people and extends over 75,000 hectares (ha), of which about 75% is not covered by urban areas (Section 3.1).

Natural capital accounting is designed to account for an organisation's assets. Some city-based accounts have therefore concentrated only on natural capital owned by the Local Authority. Natural Capital within the Tees Valley is owned and managed by a range of organisations, both public and private. Society can benefit from these assets regardless of who owns or manages it and whether or not it is accessible to the public. Furthermore, policies and decisions of the Tees Valley Combined Authority and the five Local Authorities can influence all natural capital within the Tees Valley, not just those it owns. The focus of this report therefore covers all natural capital, rather than only that owned by Local Authorities.

Natural capital accounts can also include an organisation's impacts and dependencies on natural capital outside of the relevant boundary. For example, water abstracted from natural capital outside the Tees Valley for use within it. This is usually done through the production of a natural capital income statement (or environmental profit and loss). As the focus of this report is on natural capital in the Tees Valley we do not, in general, include these (except where the impact is directly due to natural capital assets e.g. carbon emissions/sequestration). Additionally, this would be difficult to include as the objective is all natural capital within the Tees Valley, not just Local Authority owned assets, therefore it would need to account for the activities of all organisations within the Tees Valley.

2.1.2 Identifying indicators and datasets

There have been a wide range of natural capital assessments, with a variety of approaches. The indicators and datasets used in the work are varied and often based on availability of data as opposed to suitability. Natural England undertook a review of Natural Capital Indicators which identified the most important attributes of natural capital assets that enable the ongoing provision of ecosystem services, benefits and values (Lusardi et al. 2018). We were able to identify the ideal indicators for measuring change in natural capital and then compare these to available data, identifying gaps where there was nothing suitable.

The work used the natural capital logic chain (Figure 4) and described assets in terms of broad habitats. Over 80 specialists from Natural England and the Environment Agency informed this work. Indicators were identified based on a series of principles that considered how well they described the system, were sensitive to change and could infer action. Desirable datasets were those that most closely described the indicators, were regularly updated, and were accessible. The work identified indicators for the natural capital assets in terms of their extent, quality and location; the ecosystem services and benefits. This work has formed the basis of the indicators and datasets used in these accounts.

2.1.3 Mapping indicators in Natural Capital Atlases

Natural Capital Atlases map out the Natural Capital Indicators to explore the distribution and condition of natural assets both nationally (Wigley et al., 2020) and at County/City scale (Lear et al., 2020). They map natural capital quantity, quality, spatial configuration and ecosystem service flow. Data sets have been used that describe aspects of asset extent as well as hydrology, soils, nutrient and chemical status, vegetation, species composition and cultural benefits, as recommended in Natural England's Natural Capital Indicators Report.

Over 80 indicators have been mapped in each atlas, with data displayed at a 5km^2 resolution, for use at a strategic scale. The data layers are available for the series of county and city region atlases as open data products[2].

To demonstrate the link across the whole logic chain, this Account uses the Natural Capital Indicators of asset quality included in the Tees Valley Natural Capital Atlas (Lear et al., 2021), included as Appendix A. Maps from the atlas are included to show the distribution and condition of natural assets across the Tees Valley. Additionally, data from the shapefiles for the Tees Valley Natural Capital Atlas were explored and the attribute tables (included as Appendix B) for the shapefiles analysed to estimate indicators of asset quality for the Tees Valley as a whole (Section 3.2).

[2]Data layers can be downloaded at https://environment.data.gov.uk/dataset/347c87af-15fb-4775-b893-336ac10b34d7

However, estimates of asset quantity in the atlas were not in a form suitable for the account (Section 2.1.4) so were estimated using CEH's Land Cover Map (Rowland et al., 2017). Furthermore, only a limited number of ecosystem service flow indicators were possible to map in the Tees Valley Natural Capital Atlas. Therefore, ecosystem services and values also had to be estimated using other sources. This natural capital account, and others that users may produce following the same methodology, should therefore be viewed as supplements for the City/County Atlases (rather than accounts which are directly *based on data in* these atlases).

The account is supplemented by an appendix that refers to and summarises key elements of information specific to the Tees Valley (Appendix C). This information has not been used in this account as we have focussed on national datasets that could also be used to derive accounts in other areas. However, this information could provide a starting point for development of more detailed local natural accounts based on local research, data and analysis.

2.1.4 Extent of Tees Valley Natural Capital

To map asset quantity, Natural Capital Atlases used several different data sets to provide the best feasible spatial mapping of selected aspects e.g. woodland, arable and improved grassland and NE Priority habitats. However, none of these provide complete area cover, without overlap.

Instead the overall extent of natural capital included in the study was derived from geographical information. This overall stock has been split into eight broad habitat types to describe the natural capital assets in greater detail. This complies with work developed by the UK National Ecosystem Assessment (UKNEA, 2011) and is consistent with the Office for National statistics UK Ecosystem Accounts (ONS, 2017a). Habitats are particularly useful for describing natural capital assets as we can attribute them to places on the ground, in this case the boundary of the TVCA, and we have categorised them into non-overlapping broad habitat types i.e. land can't be categorised as both a woodland and a grassland, unlike the asset quantity indicators included in the Tees Atlas.

In order to derive predominant Broad Habitats, we used the Centre of Ecology and Hydrology's (CEH) Land Cover Map 2015 (LCM2015) data to map out 21 LCM classes into the 8 broader classes (Table 10). The LCM dataset is created by classifying two-date composite images captured by satellite (CEH, 2017).

2.1.5 Asset quality

Alongside the quantity of the natural capital asset (extent), the quality of the asset is also critical in determining its ability to potentially provide sustainable ecosystem services and benefits into the future. Natural England (Lusardi et al., 2018) identified seven categories of the most important indicators for understanding asset quality illustrated in Table 5.

Table 5 Key asset quality categories and associated indicators

Asset quality category	Indicator
Hydrology and geomorphology	naturalness of water levels, flows, flooding, aquifer function, lake hydrological regime and extent of artificial drainage.
Nutrient/chemical status	of water, soil and air/atmospheric deposition.
Soil/sediment processes	carbon, biota, peat depth, coastal sediment supply.
Species composition	naturalness of biological assemblage, absence of invasive non-native species, plant species diversity, presence and frequency of pollinator larval & adult food plant and marine net productivity, by species.
Vegetation	ratio of vegetation to bare soil, plant growth rate, surface vegetation roughness, proportion of peat mass actively forming peat, vegetation structure/structural diversity, extent and condition of linear features & pockets of semi-natural vegetation (in farmland) and vegetation next to water courses.
Cultural	1.1 Nature: visibility of wildlife, presence of flagship and/or rare species, species diversity, naturalness of watercourses, favourable condition of SSSIs and designated geosites. 1.2 Landscape: boundary features – type, length and condition; size of environmental space 1.3 Culture and history: designated historic environment assets. 1.4 Quietness: tranquillity. 1.5 Facilities: number of organised events, presence of clubs, schools, training centres. 1.6 Accessibility: perimeter access points, density of public rights of way / permissive paths.
Geodiversity	favourable condition of designated geosites, active geomorphological processes.

Asset quality indicators have been chosen as a set of indicators that represent the state of the environment across this range of functions (e.g. hydrology, species composition), using nationally available and accessible data. Where possible, datasets are based on the indicators mapped in the City/County Natural Capital Atlases, either using the Tees Valley attribute table data or the original dataset. Atlas indicators have been supplemented with additional publicly available datasets where necessary.

The asset quality indicators included in the extended balance sheet are only a representation of potential indicators. They are not an exhaustive list that fully demonstrates the quality of natural capital in the Tees Valley. As such, it is important that the extended balance sheet is viewed alongside the Natural Capital Atlas, which provides more evidence both in terms of the range of indicators and how quality varies across the area and compares nationally.

Geodiversity considerations have been included in datasets on protected sites and hasn't been dealt with separately because of the lack of specific geological datasets suitable for the accounts.

Where additional datasets have been sourced to supplement the Natural Capital Atlas indicators we have followed the principles of good indicators in accordance with the recommendations of the indicators report (Lusardi et al. 2018). The datasets needed to be of sufficient resolution that they could be cut to the TVCA boundary and, ideally, regularly updated.

Table 6 below summarises the indicators and associated measures we have included for each asset category. For each indicator we set out the datasets we have used in this study, with the release date of each. Where we have used indicators from the Tees Valley Natural Capital Atlas we include the Natural Capital Atlas map ID in italic. For Atlas indicators that use Natural England and CEH's 'Mapping Natural Capital' project data (CEH and Natural England, 2016) we have used the original data rather than the Natural Capital Atlas data as it is available at a more granular level. Where this is the case, the Natural Capital Atlas references are in square brackets.

Table 6 Asset quality indicators, measures and datasets

Category	Indicator ***(Natural Capital Atlas map ID in italic)***	Indicator measure and unit	Dataset
i) Hydrology and geomorphology	Natural Aquifer Function *(ID: 51)*	Ground water quantity status (WFD) % good	Environment Agency WFD Groundwater Bodies Cycle 2, 2016
	Naturalness of Flow Regime *(ID: 52)*	Hydrological status (WFD) % good	Environment Agency's WFD Water Body Water Status, 2016, and WFD

			River Waterbodies Cycle 2, 2016
	Quality of bathing waters *(not in atlases)*	Bathing water quality % good	Environment Agency's Bathing Water Quality data, 2019
ii) Nutrient and chemical status	Nutrient Status of Water Bodies *(ID: 56)*	Surface water quality nutrient status (WFD) % good	Environment Agency's WFD Water Body Water Status, 2016, and WFD River Waterbodies Cycle 2, 2016
iii) Soil/sediment processes	Soil Carbon/Organic Matter *[ID: 59]*	Mean estimate of soil organic carbon in topsoil (0-15cm depth) Tonnes/ha	Natural England and CEH's 'Mapping Natural Capital' project: Soil carbon (Henrys et al., 2012a).
	Soil Biota *[ID: 60]*	Soil invertebrate abundance, mean estimate of total abundance in topsoil (0–8cm depth soil core) Mean count	Natural England and CEH's 'Mapping Natural Capital' project: Soil invertebrates (Henrys et al., 2012b).
iv) Species composition	No indicators included but species composition is also demonstrated by the soil invertebrate abundance and nectar plant diversity indicators		
v) Vegetation	Presence & Frequency of	Nectar plant diversity, mean estimate of number of nectar	Natural England and CEH's 'Mapping Natural Capital' project: Nectar

	Pollinator Food Plants *[ID: 62]*	plant species for bees (per 2×2m plot) Mean count	plant diversity for bees (Maskell et al., 2016).
vi) Cultural	Favourable Condition of SSSIs *(ID: 65)*	Percentage of area under a Site of Special Scientific Interest (SSSI) which is in favourable condition % favourable	Natural England's SSSI Units dataset, 2019
	Public Rights of Way *(ID: 68)*	Public Rights of Way Km/ha	Open Local Authority datasets derived from multiple sources, directed from the rowmaps website: www.rowmaps.com, 2018
	Designated Historic Environment Assets (World Heritage Sites, Scheduled monuments (% at risk), Historic Parks & Gardens, Listed Buildings, Conservation Area) *(ID: 66)*	Area of designated historic environment assets Ha	Historic England's designated sites datasets – Scheduled Monuments, World Heritage Sites, Registered Battlefields and Registered Parks and Gardens, 2018
		Scheduled Monuments at Risk Ha	Historic England's Scheduled Monuments at Risk dataset, 2018

2.2 Ecosystem services

The ecosystem assets of the Tees Valley deliver a wide range of ecosystem services. Provisioning services include production of timber and wood products, fish and marine products harvested from the sea, crop and livestock production and provision of fresh water. Regulating services include climate regulation, water quality, flood protection and improvement of air quality via removal of particulates by vegetation. Cultural services include experiential, physical use, scientific and educational use and cultural appreciation of nature. The quantity, quality and location of assets influence this ecosystem service delivery, as does management and external pressures.

The ecosystem service categories have been based on the Common International Classification of Ecosystem Services v4.3 (CICES, 2013), again to ensure consistency with ONS, and international approaches. CICES does not include supporting ecosystem services but defines "*ecosystem function*" as underpinning the provision of ecosystem services. Ecosystem function is captured in the metrics for natural capital quantity and quality. We have renamed a number of the CICES categories to enable better understanding for a less technical audience. For regulating and provisioning services indicators for ecosystem services are a measure of the flow of the services. For cultural services the flows of ecosystem services are represented by the interactions people have with the natural environment (practices). The categories we have considered are those where there is a physical interaction with the environment, and those where there is an intellectual interaction. The list of services considered are in Table 7.

Table 7 Ecosystem services considered with the associated descriptions of benefits

Ecosystem service (based on CICES v. 4.3)	Plain English name adopted in Tees natural capital account	Description of benefits
Materials from plants, animals & algae	Timber and other materials	Materials e.g. hay, grass for fodder, timber (separate data on hay and grass production is not available so this is included under 'Crops)
Wild animals & their outputs	Fish, marine products and game	Game, freshwater fish, marine fish and shellfish. Includes commercial and subsistence fishing and hunting for food
Aquaculture	Aquaculture	Products from aquaculture e.g. fish, shellfish & seaweed for food, fertiliser, angling bait, medicines
Cultivated crops	Crops	Food from crops e.g. cereals, vegetables, fruit
Water supply	Water supply	Plentiful water e.g. water for drinking, domestic use, irrigation, livestock, industrial use including cooling, wildlife

Reared animals & their outputs	Livestock	Products from animals e.g. meat, dairy products, honey
Water quality	Clean water	Clean water, also underpinning e.g. water supply, sustainable ecosystems, cultural services, health benefits.
Air quality	Clean air	Clean air, also underpinning health benefits and sustainable ecosystems
Pollution regulation	Pollution regulation	Regulation of pollution by vegetation e.g. particulates ($PM_{2.5}$) removed by woodland
Noise regulation	Noise regulation	Health benefits e.g. reduced stress, hypertension, hearing impairment; benefits to sustainable ecosystems through reduction in disturbance; reduced impacts on educational & work performance
Mass stabilisation and control of erosion rates	Erosion control	Erosion control e.g. soil/land retention, lack of transport disruption, protection of housing, businesses & infrastructure, reduced health & safety risk, reduced flood risk
Flood protection	Flood protection	Reduced flood risk, affecting e.g. reduced health & safety risk, protection of housing, businesses & infrastructure, lack of transport disruption
Pollination & seed dispersal	Pollination	Pollination underpinning cultivated crops dependent on insect pollination e.g. field beans, apples, plums, pears, cucumbers, plums, strawberries, oil seed rape
Maintenance of nursery populations and habitats	Thriving wildlife	Biodiversity, in of itself, and underpinning all other services such as recreation (including wildlife watching), tourism, research and education, food from wild populations & aquaculture, flood protection (sea grass beds, dunes), climate regulation

Pest & disease control	Pest and disease control	Natural control of agricultural pest species and diseases
Global, regional & local climate regulation	Climate regulation	Equable climate e.g. reduced risk of drought, flood & extreme weather events, lower summer temperatures, reduced health & safety risks, reduced flood risk, protection of infrastructure/lack of transport disruption
Cultural services	Cultural Services (recreation, tourism and volunteering) Cultural Services (scientific and educational) Cultural Services (appreciation of nature)	Cultural wellbeing. This includes: Capabilities e.g. knowledge, health, dexterity, judgement Experiences e.g. tranquillity, inspiration, escape, discovery Identities e.g. belonging, sense of place, rootedness, spirituality, sense of history Non-use values: existence, bequest, altruistic, option

We can quantify only a proportion of these ecosystem services. Where we are able to quantify the ecosystem services we do so based on a combination of evidence and assumptions. For example, the number of recreational visits is based on an econometric model and national data set, rather than detailed local measurements. We therefore have less confidence in these figures at a local level and estimates should be considered within this context (Section 2.3.3).

Similarly, there are important ecosystem services which we are unable to quantify. To give one example, land maintained as woodland will hold and slow down water, reducing flooding downstream, but there is no national data set or tool that would enable a non-specialist to estimate the scale of flow reduction and associated reduction in flood risk for the TVCA area. Similarly, there is no public data set that provides an overview of crop, livestock and timber production at Local Authority level. Where possible, we include information on asset quantity (e.g. cropped area) instead where they provide a reasonable proxy for the service. We also provide related information that is available where this provides some additional context on the service.

There is a consistent pattern to which services and benefits are easiest to quantify and value with services such as thriving wildlife and natural beauty often omitted. In this account we try to reduce this problem by estimating the significance of benefits that we do not quantify and drawing attention to these judgements in the discussion of our results.

Another consideration is whether to exclude some services based on a consideration of their materiality i.e. whether their inclusion has the potential to impact on decisions. For example, in our NNR Accounts we excluded some ecosystem service categories that were generally of minor significance for NNRs, such as minerals, fossil fuels, air pollution removal and urban cooling. In this Account we exclude services that are generally of low significance, such as wild plants and aquaculture. We also exclude minerals, fossil fuels and renewable energy since these provisioning services are generally well understood and documented elsewhere and their inclusion would not change how this natural capital account influences decision-making.

2.3 Benefits and values

Society values natural capital for the enjoyment people gain from these assets and the benefits they provide. We have assessed the significance of these benefits and where possible have estimated their monetary value.

Benefits that we have been able to value in monetary terms include recreation, cleaner air, carbon sequestration from non-arable or freshwater habitats, fisheries, crops and livestock. Costs that we have been able to value in monetary terms are the cost of carbon emissions from arable land and freshwater.

Values have been estimated using a range of techniques. Primary valuation studies were out of scope for this natural capital account as they are costly and would not be easily replicable in other areas. Values therefore rely on existing open, publicly available evidence, datasets and tools. Detail on the specific methods and assumptions that underlie each value are provided in Section 5.

Where quantified data is missing, we have estimated the significance of ecosystem service provision and benefits qualitatively (Section 2.3.2). For quantified values, we use confidence levels (shown as a Red – Amber – Green traffic light rating) to indicate the quality and appropriateness of the information behind the value figures (Section 2.3.3). We did this to reduce the risk of values being misinterpreted and to present a more complete picture to decision-makers.

2.3.1 Natural Capital Asset values

We estimate natural capital asset values from the value of annual ecosystem service flows as recommended by ONS (2017b), namely 100-year asset life and a declining discount rate (3.5% up to 30 years; 3.0% for 31 to 75 years; 2.5% for 76 to 100 years). These values assume that the value of flows remain at present levels giving a multiplier of 29.86 of annual value (except for carbon as detailed in Section 5.1.4).

2.3.2 Significance ratings

Assessment of significance allows us to focus on important services regardless of whether they can be quantified or valued. It reduces the risk of partial valuation being misinterpreted and allows us to present a more complete picture to decision makers. For example, the value of benefits from a provisioning service may be £5 million. These benefits may be assessed as being of *relatively low significance* across the selected area. Biodiversity may be assessed as having *high* significance, but benefits cannot be valued in monetary terms.

We interpret significance broadly; anything that provides social and/or economic benefits to local people and other stakeholders is considered to be significant. The assessment is based on a scale with four levels, each service being assigned a score of 0 (none), 1 (low), 2 (medium) or 3 (high).

Table 8 Significance levels

Significance	**The ecosystem service provides socioeconomic benefits that are…**	
0	None	Very low/minor or absent
1	Low	Relatively low across the selected area
2	Medium	'Medium' across the selected area
3	High	High across the selected area

We note that several different interpretations of significance are possible including:

- Assessment based on the opinion of a defined group of experts using established criteria;
- Assessment of whether ecosystem services are of national, regional or local importance as in National Character Area profiles (Natural England, 2013);
- Assessment of significance based on the opinions of a sample or selected group of local stakeholders (the approach adopted in this project).

In all cases the results of the assessment will depend on who is asked and the criteria or other methods that they use to decide on the level of significance to assign to each benefit category. In this report we based our assessment on an exploratory exercise conducted with a small group of local stakeholders from the project steering committee. This has the advantage of encouraging local engagement. Local stakeholders engaged with the local natural capital account and have had an opportunity to state their views on the significance of different categories of benefit.

The exploratory exercise consisted of the following main steps:

1. The convenor explained the purpose of the exercise, including the need to rank ecosystem services into four significance categories
2. Participants/stakeholders were divided into groups (2 to 4 people in each group). Each group was provided with instructions and assessment sheets (Appendix D)
3. Groups discussed the significance of each service/benefit and reached an agreed assessment to record on the sheets for ecosystem services and benefits

4. The convenor shared results with all stakeholders and identified differences
5. The convenor facilitated as all stakeholders discussed these results and reached consensus.

Note: Significance may be assessed separately for ecosystem services and for benefits. However, participants found it hard to separate these so we have included the results for the significance of benefits only. The assessment method can be developed further and this is discussed in Section 8 below.

2.3.3 Uncertainty

Natural capital accounting is an exercise in decision-support. It aims to gather, assess and make sense of disparate data to allow land managers, owners or decision-makers to better understand their assets. It is therefore essential that they understand the confidence with which any findings are presented to them (HM Government 2010, HM Treasury 2020). This is particularly important where there is a wide range of confidence levels in the information offered, which is the case for natural capital accounting. It is equally important that managers understand the significance of evidence gaps. It is possible to explicitly consider uncertainties and evidence gaps in the analysis of specific projects, because we know which decision we are trying to support. However, natural capital accounts can be used to support a wide range of decisions so it is especially important to be clear about uncertainties and evidence gaps.

Approaches to reporting uncertainty need to be proportionate and transparent. Many of the final results of this study are qualitative judgements. Where this is the case we have explained our confidence in the findings qualitatively. For final quantitative judgements we have developed a traffic light system (RAG) to rate accuracy. The methodology is set out below.

Table 9 Description of Red Amber Green (RAG) ratings

Definition	Colour
We may have used some assumptions or estimation but consider these figures uncontroversial.	Green
We have used some assumptions or estimation and some of these may be open to question. Accuracy is better than + or -50%.	Amber
We are confident that the number is in the right order of magnitude. Order of magnitude implies that for an estimate of 5 that we are confident that the real figure is within the range 0.5 to 50.	Red
We can't offer a number which is likely to be in the right order of magnitude. This is due to unquantifiable uncertainty in the science, valuation or the relationship between them. What we do know, and our confidence, will be discussed qualitatively.	No number

We have placed the RAG rating on the final number in a calculation sequence and the RAG rating represents our understanding of all the uncertainties up to that point. The reasons for our judgements are set out in the results section.

2.4 Decision-making case study

Our case study explores the use of natural capital accounting to improve project planning for delivering net zero carbon from land use and natural capital in the area by 2040. We reviewed the literature to identify viable approaches to emissions reduction and develop a set of actions that will deliver net zero carbon. We assess the wider range of benefits that this will deliver and the impact this has on the natural capital account. We outline the benefits of a net zero carbon scenario but do not fully specify all gains and losses and do not appraise the benefits of the scenario against the costs. The study is summarised in Section 7.

2.5 Costs

Natural capital accounts usually look to include the costs to maintain assets. In this study we include all natural capital within the Tees Valley area, rather than just the land owned and managed by Local Authorities. It was therefore too complex to estimate maintenance costs within the constraints of this project.

3 Asset register

This section sets out the outputs from quantifying the extent and quality of natural capital assets. For each indicator, it includes the description, method, result for the whole of the Tees Valley and, where relevant, the map from the Tees Valley Natural Capital Atlas to demonstrate how each indicator varies across the Tees Valley. Indicators have been compiled into asset themes for presentation (including habitat extent in addition to the six habitat quality themes outlined in Section 2.1.5).

3.1 Habitat extent

The total area of the Tees Valley is about 75,000 hectares, of which over 25% is categorised as urban (20,600 ha). Of the remaining land, the vast majority is enclosed farmland (44,500) and woodland (4,800 ha). Table 10 provides a full breakdown of the TVCA area, by broad habitat and LCM2015 class (Rowland et al., 2017).

Table 10 The relationship between National Ecosystem Assessment (NEA) Broad Habitats and LCM2015 classes, and hectarage values across Tees Valley

National Ecosystem Assessment Broad Habitat (NEA-BH)	LCM2015 Class	Area across Tees Valley (ha)	Percentage of Tees Valley area
Woodlands	1 Broadleaved woodland	4,123	5.5%
	2 Coniferous woodland	666	0.9%
Enclosed farmland	3 Arable and horticulture	29,128	38.8%
	4 Improved grassland	15,333	20.4%
Semi-natural grassland	5 Neutral grassland	1,359	1.8%
	6 Calcareous grassland	13	0.0%
	7 Acid grassland	37	0.0%
Open water, wetlands, floodplains	8 Fen, marsh and swamp	157	0.2%
	11 Bog	-	-
	14 Freshwater	574	0.8%

Mountains, moorlands, heaths	9 Heather	8	0.0%
	10 Heather grassland	147	0.2%
	12 Inland rock	105	0.1%
Marine	13 Salt water	847	1.1%
	17 Littoral rock	191	0.3%
	18 Littoral sediment	975	1.3%
Coastal margins	15 Supra-littoral rock	-	-
	16 Supra-littoral sediment	322	0.4%
	19 Saltmarsh	537	0.7%
Urban[3]	20 Urban	8,116	10.8%
	21 Suburban	12,481	16.6%
TOTAL		75,122	

The above data uses the LCM2015 dataset as it provides complete area cover without overlap which the Tees Valley Natural Capital Atlas does not. Natural Capital Atlases used several different data sets to provide the best feasible spatial mapping of selected aspects e.g. woodland, arable and improved grassland and NE Priority habitats. Asset quantity estimates from the Natural Capital Atlas are summarised on page 50 of the Tees Valley Natural Capital Atlas (Appendix A).

3.1.1 Marine habitats

The LCM2015 dataset only covers a limited proportion of the UK marine area. For example, saltwater only covers land and tidal areas, not sea.

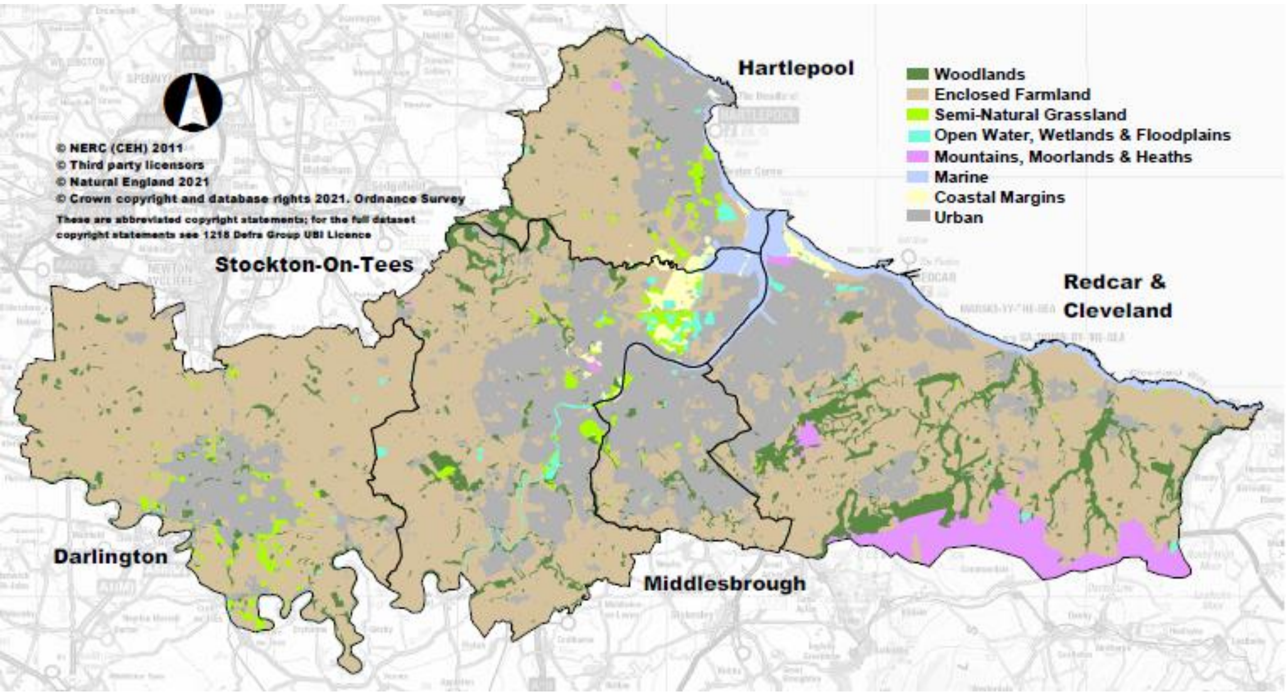
[3] 'Urban' includes the whole area classified as urban by the LCM 2015 dataset. This will include urban habitats such as parks and gardens, as well as general urban areas, such as roads, houses, and other infrastructure. Actual amounts of Urban habitats have not been calculated in this account.

Alternatively, the Tees Natural Capital Atlas maps marine habitats up to 12 nautical miles from the coastline. Using this definition, the extent is similar to the total Tees Valley land area mapped using LCM2015, about 72,500 ha. Our asset quality maps therefore demonstrate a much greater area of marine habitat than reported in Table 10, above. Where relevant, our analysis of asset quality and ecosystem services is based on the area covered by the Tees Valley Natural Capital Atlas.

3.1.2 Distribution of habitats

Figure 6, below, demonstrates the classification of land across the Tees Valley by NEA Broad Habitat. Urban areas are particularly focused around the Tees Estuary and River Tees. Enclosed farmland is spread across the rest of the Tees Valley. Woodland is particularly predominant to the east of the Tees Valley in Redcar and Cleveland. Although only covering a small total area, there is an important area of mountains, moorlands and heaths found in the south east where the North York Moors crosses the boundary of Redcar and Cleveland.

Figure 6 Tees Valley land cover based on NEA broad habitat



3.2 Asset quality

Table 11, below, summarises the results of our assessment of asset quality indicators.

Table 11 Asset quality indicators

Natural capital asset baseline		
Asset Attribute	**Indicator**	**Value**
Extent	Total area (ha)	75,000
Hydrology	Ground water quantity status (% good) Water Framework Directive (WFD)	69%
	Hydrological status (% good) WFD	19%
	Bathing water quality (% good)	100%
Nutrient/ Chemical status	Surface water quality status (% good) WFD	37%
Soil/ sediment processes	Mean Estimates of Soil Organic Carbon in Topsoil, 0-15cm depth (tonnes per ha)	52.7
	Soil invertebrate abundance, mean estimates of total abundance in topsoil (0–8cm depth soil core)	40.0
Species Composition		
Vegetation	Nectar plant diversity, mean estimates of number of nectar plant species for bees (per 2×2m plot)	4.2
Cultural	% area of Sites of Special Scientific Interest in favourable condition	51%
	Public rights of way (km/ha)	0.012
	Area of designated historic environment assets (ha)	535
	Scheduled monuments at risk (ha)	148

The sections below offer further detail for each asset quality category and indicator, including:

- the ecosystem services that they support;
- the measure used to represent the indicator;
- the methodologies followed;
- comparisons of results with national estimates; and
- maps demonstrating how indicator values vary across the Tees Valley.

Further detail on reasons for selection of the indicators and datasets, as well as other alternative indicators, can be found in the Natural Capital Indicators report and Natural Capital Atlases.

For indicators that were included in the Natural Capital Atlas, the data and calculations are included in Appendix B.

Note: for the calculations based on the Tees Valley Natural Capital Atlas we used an alternative version of Atlas data to that which is available in the shapefiles published alongside the City/County Natural Capital Atlases (Section 2.1.3). This was because for some indicators, the data was not in a format that could be used to estimate asset quality indicators. For example, for indicators where we used WFD data this account reports the percentage of length of river classified as good. However, the final approach chosen in the county/city scale natural capital atlases was to present the raw WFD data to show the variation of quality across the area.

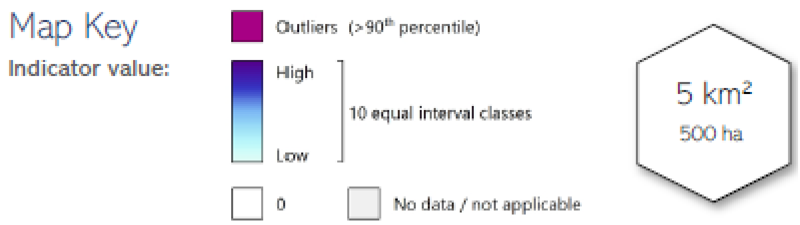
Additionally, the Tees Valley Atlas and attribute tables were specifically produced for this project as the Tees Valley did not originally have its own Natural Capital Atlas – instead it was combined with the North East Combined Authority for presentational purposes.

Where relevant, for each indicator we include the relevant map from the Tees Valley Natural Capital Atlas. The maps show values summarised by $5km^2$ hexagons, which are then symbolised using a colour scale based on the values across the whole country. The legend below gives a generalised key of the map colours. In order to see variation amongst the bulk of the data values, the highest 10% of values per hexagon are separated from the rest and symbolised as ‘outliers’ (coloured purple on the map). This is purely for visualisation purposes. The remaining per hexagon values are divided into 10 equal interval classes and are symbolised using a colour gradient (shades of blue)[4]. Values of zero are shown as white and hexagons with no data or not applicable as grey.

[4] For example, if per hexagon values for an indicator range from 0km to 5km, with 90% of data between 0km and 2km, values between 2km and 5km would be symbolised as ‘outliers’. The remaining per hexagon values would be divided into 10 equal interval classes, each with a range of 0.2km (0 to 0.2km, 0.2 to 0.4km up to 1.8 to 2km). The number of hexagons in each class will therefore vary dependent on the distribution of values.

The generalised key for each map is as follows, with the low, high and outlier values reported alongside each map.

Figure 7 Generalised map key for Natural Capital Atlas maps



For indicators using WFD data, actual river/groundwater data has been mapped to show different statuses, rather than summarising into hexagons. Where this is the case, the map-specific key is presented.

Where possible we have included some information to provide context for the figures. For each indicator we include a comparison of the overall estimate for the Tees Valley with national estimates. However, although we provide a comparison, we have not explored why differences exist. Conclusions should not therefore be drawn from this without further analysis, for example of causal factors. Similarly, we provide descriptions of how indicators vary across the Tees Valley using the map from the Natural Capital Atlas, which in some case refers to habitats that coincide with high or low values. Again, we have not explored the extent to which there is a causal link so, unless stated, relationships should not be inferred.

3.2.1 Hydrology and Geomorphology

These aspects of asset quality assessed are particularly important in supporting the following ecosystem services: clean water; water supply; thriving wildlife; and cultural services.

Natural aquifer function

Natural aquifer function is measured using WFD ground water quantity status. Ground water quantity status is described as ‘good’ when the long-term available water resource is not exceeded by the long-term rate of abstraction. This includes consideration of flow required to achieve good ecological status.

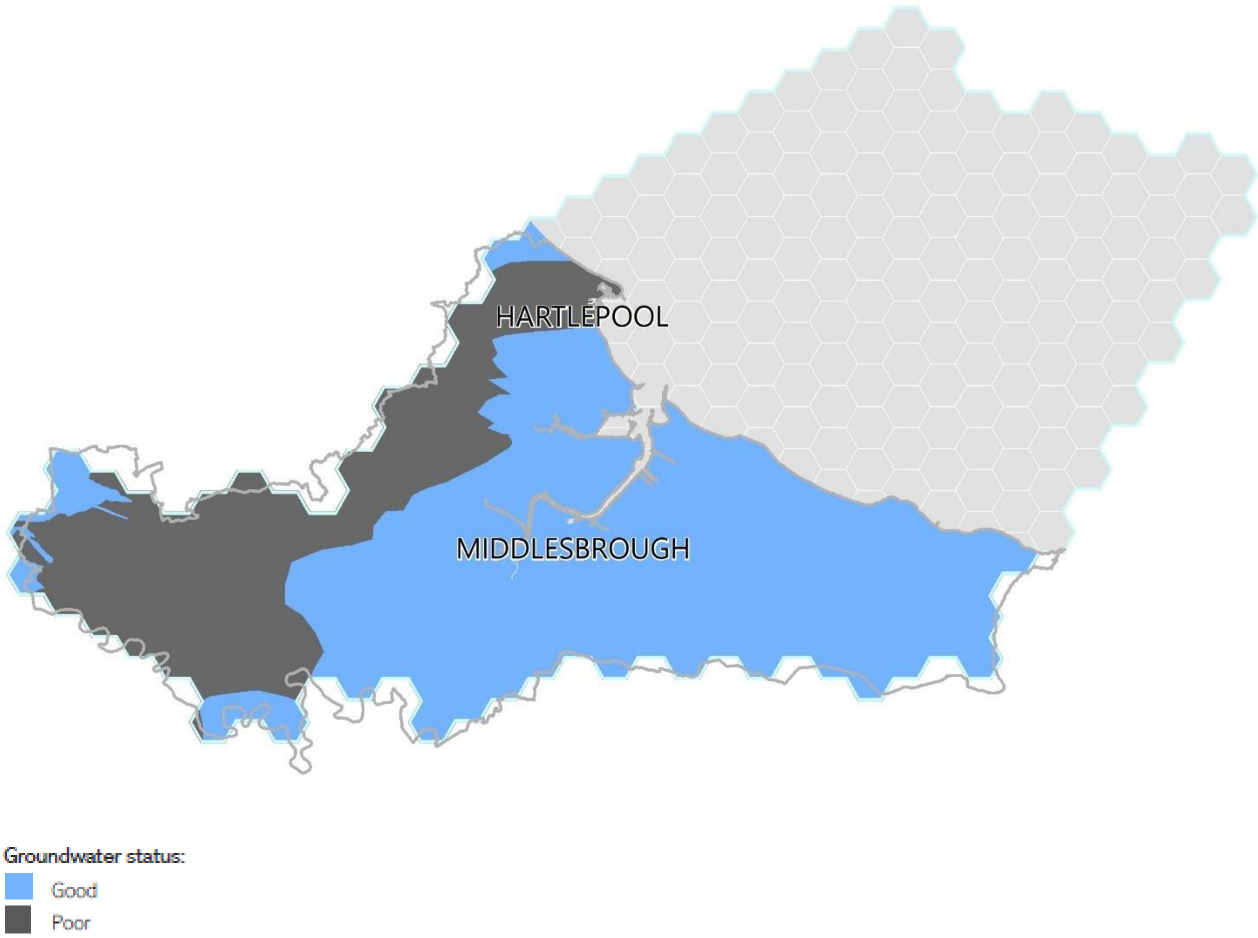
The measure for this indicator is the percentage of groundwater catchment area with ‘good’ quantitative status for WFD 2016. It is estimated using the Atlas attribute table, which is based on EA’s WFD data and groundwater catchment boundaries, cycle 2 (EA, 2016a).

Using the Natural Capital Atlas data, the total groundwater area within the Tees Valley is 78,600 ha. Of this, 54,200 ha is categorised with ‘good’ WFD quantitative status. 69% of groundwater catchment area is therefore categorised as ‘good’ (= 54,200/78,600). Figure

8 below shows the area of groundwater catchment with 'good' quantitative status for WFD 2016 shown in blue.

To provide context, using Natural Capital Atlas data for the whole of England, nationally 72% of groundwater area is categorised as good. The Tees Valley is, therefore, fairly typical of the national picture. As shown in Figure 8, groundwater area categorised as good is situated across the central, south and east of the Tees Valley.

Figure 8 Natural aquifer function



Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021, using © Environment Agency 2016 WFD Groundwater Bodies Cycle 2 database.

Naturalness of flow regime

This indicator is measured using WFD hydrological regime classification, which describes the naturalness of river flows. 'High' status signifies the quantity and dynamics of flow, and the resultant connection to groundwaters, reflect totally, or nearly totally, undisturbed conditions.

The measure for this indicator is the percentage of rivers assessed under the Water Framework Directive with 'high' WFD hydrological status in 2016, using EA's WFD data and river water bodies, cycle 2 (EA, 2016b).

Using the Natural Capital Atlas data, the total length of rivers assessed under the Water Framework Directive within the Tees Valley is 375 km. Of this, 70 km is categorised with ‘high’ WFD hydrological status. 19% of river length is therefore categorised as ‘high’ (= 70/375). Figure 9 below shows the distribution of rivers with ‘high’ WFD hydrological status in 2016, shown in blue.

Although this percentage figure is low, using Natural Capital Atlas data for the whole of England, nationally only 24% is categorised as ‘high’ so the Tees Valley is typical of the national picture. As shown in Figure 9, rivers categorised as high are situated across the west, south and east of the Tees Valley.

Figure 9 Naturalness of flow regime

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021, using © Environment Agency 2016 WFD Water Body Water Status and WFD River Waterbodies Cycle 2 datasets.

Quality of bathing waters

Bathing waters are places, designated by legislation, where there is a statutory requirement to monitor and report on the quality of bathing waters during the bathing-water season to ensure that designated bathing water sites on the coast and inland are safe and clean for swimming and other activities.

The measure for this indicator is the percentage of designated bathing waters within the Tees Valley with ‘good’ or ‘excellent’ status in 2019, estimated using the Environment Agency’s Bathing Water Quality data, 2019 (EA, 2019a). Classifications are based on samples taken from 2016 through to 2019.

There are 9 designated bathing waters on the coast within the TVCA area – 6 in Redcar & Cleveland and 3 in Hartlepool. Of these 9 bathing waters, 6 are classified as 'excellent' and 3 as 'good'. Therefore, 100% are classified as 'good' or 'excellent'.

Nationally there are 421 bathing waters in England. Of these, 71% are classified as excellent and 22% as good. Therefore 93% are good or excellent. Bathing waters in the Tees Valley are therefore higher than the national picture for at least good and similar for excellent (67%).

3.2.2 Nutrient/chemical status

The aspects of asset quality assessed for nutrient/chemical status are important in supporting the following ecosystem services: fish, marine products and game; timber and other materials; aquaculture; clean water; clean air; pollination; thriving wildlife; and cultural services.

Nutrient Status of Water Bodies

This indicator is measured using WFD surface water quality nutrient status. High levels of phosphorus in rivers can cause freshwater eutrophication. The main sources are sewage effluent and agricultural runoff. Phosphorus is the most common reason for water bodies not to achieve good status. Ecosystem assets play an important role in mediating and diluting nutrient loads.

The measure for this indicator is the percentage of rivers assessed under the Water Framework Directive with 'good' or 'high' status for phosphate levels for WFD in 2016. It is estimated using the Atlas attribute table, which is based on EA's WFD data and river water bodies, cycle 2 (EA, 2016c).

Using the Natural Capital Atlas data, the total length of rivers assessed under the Water Framework Directive within the Tees Valley is 375 km. Of this, 139 km is categorised with 'good' or 'high' WFD status for phosphate levels. 37% of river length is therefore categorised as 'good' or 'high' (= 139/375). Figure 10 below shows the length of river with 'good' or 'high' WFD status for phosphate levels in 2016, shown in blue.

Although this percentage figure is low, using Natural Capital Atlas data for the whole of England, nationally 44% is categorised as 'high' so the Tees Valley is again only slightly below the average for the whole of England. As shown in Figure 10, rivers categorised as high are primarily situated in the predominantly woodland and dwarf shrub heath area to the east of the Tees Valley.

Figure 10 Nutrient status of water bodies

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021, using © Environment Agency 2016 WFD Water Body Water Status and WFD River Waterbodies Cycle 2 datasets.

3.2.3 Soil/sediment process

The aspects of asset quality assessed for soil/sediment processes are important in supporting the following ecosystem services: crops; livestock; clean water; erosion control; thriving wildlife; and climate regulation.

Soil carbon/organic matter

CEH note that "Soil organic carbon is essential for its role as the primary energy source in soils. It is vital for maintaining soil structural condition, resilience and water retention. As soil carbon is the biosphere's largest carbon reservoir, soils play a vital role in climate regulation" (CEH and Natural England, 2016).

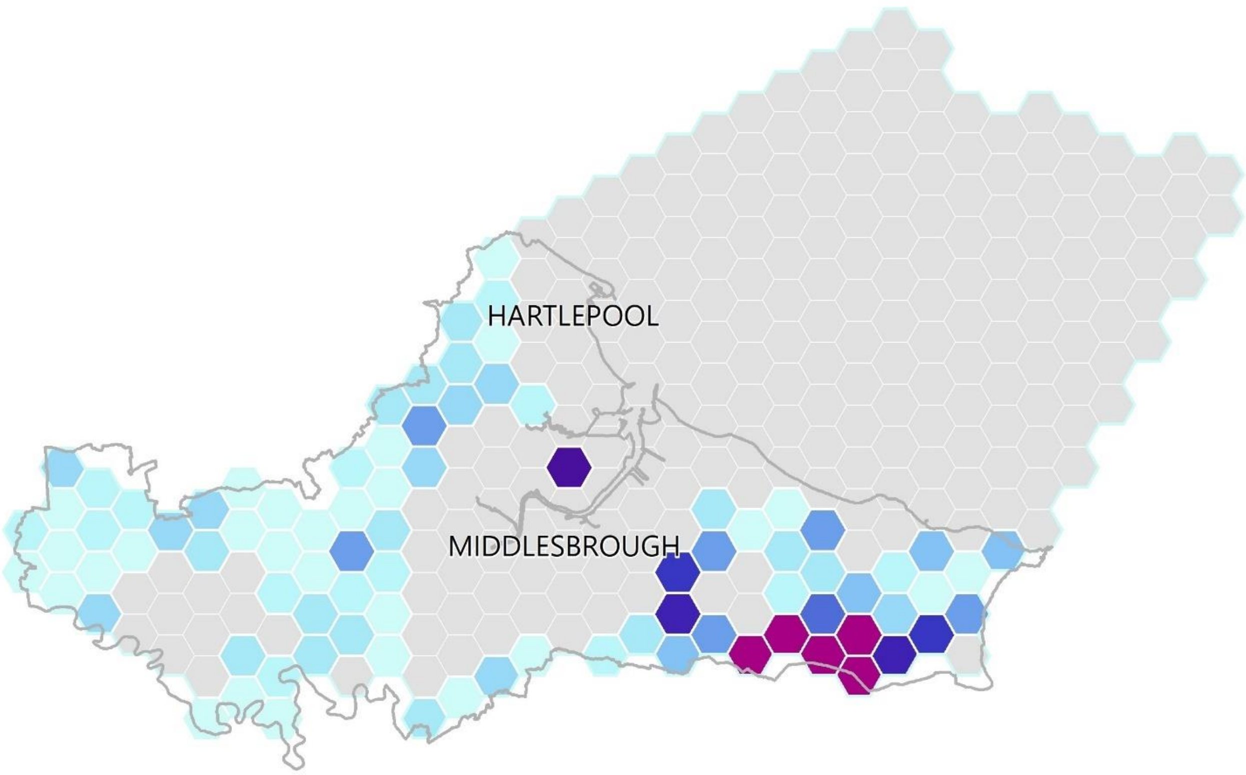
The measure for this indicator is the mean estimate of carbon density in topsoil (0-15cm depth) – tonnes per hectare, estimated using Natural England and CEH's 'Mapping Natural Capital' project: Soil carbon (Henrys et al., 2012a).

This dataset is statistically extrapolated to a national level from CEH Countryside Survey data 2007. It does not include areas such as urban and littoral rock that are not surveyed in the Countryside Survey. Additionally, in some circumstances sample sizes for particular land parcel categories were insufficient to estimate mean values. The estimate is therefore only for land parcels with data, covering 52,528 ha. The weighted average (by size of land parcels) = 52.7 tonnes per hectare.

To estimate this indicator we have used the original CEH dataset rather than the Natural Capital Atlas data as it is available at a more granular resolution (1km²) than that mapped in the Atlas (5km²). However, because we have used the same dataset as that used to map Soil Carbon/Organic Matter (ID: 59) in the Natural Capital Atlas we are still able to show how the indicator varies across the Tees Valley and how it compares nationally. Figure 11, taken from the Atlas, shows how the mean estimate varies across the Tees Valley at 5km² resolution.

Using the Natural Capital Atlas data, the average of all hexagons with data across the whole of England is higher than the Tees Valley at 59.5 tonnes per hectare. The map shows that there is a small ‘pocket’ of hexagons with high carbon density in topsoil (purple and dark blue hexagons) in the woodland and dwarf shrub heath area to the south east of the Tees Valley where it joins with the North York Moors.

Figure 11 Soil carbon/organic matter



Hexagon values: 45.64 – 74.73 t; Outliers 74.73 – 101.27 t

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021. Contains data supplied by © NERC – Centre for Ecology & Hydrology.

Soil biota

This indicator is measured using soil invertebrate abundance. CEH note that "Soil invertebrates have an important role in soil processes. This includes storing, filtering and transforming nutrients, as well as plant growth. Soil invertebrates are fundamental to maintaining soil quality, which underpins almost all other regulating ecosystem services." (CEH and Natural England, 2016). This indicator is also relevant for species composition.

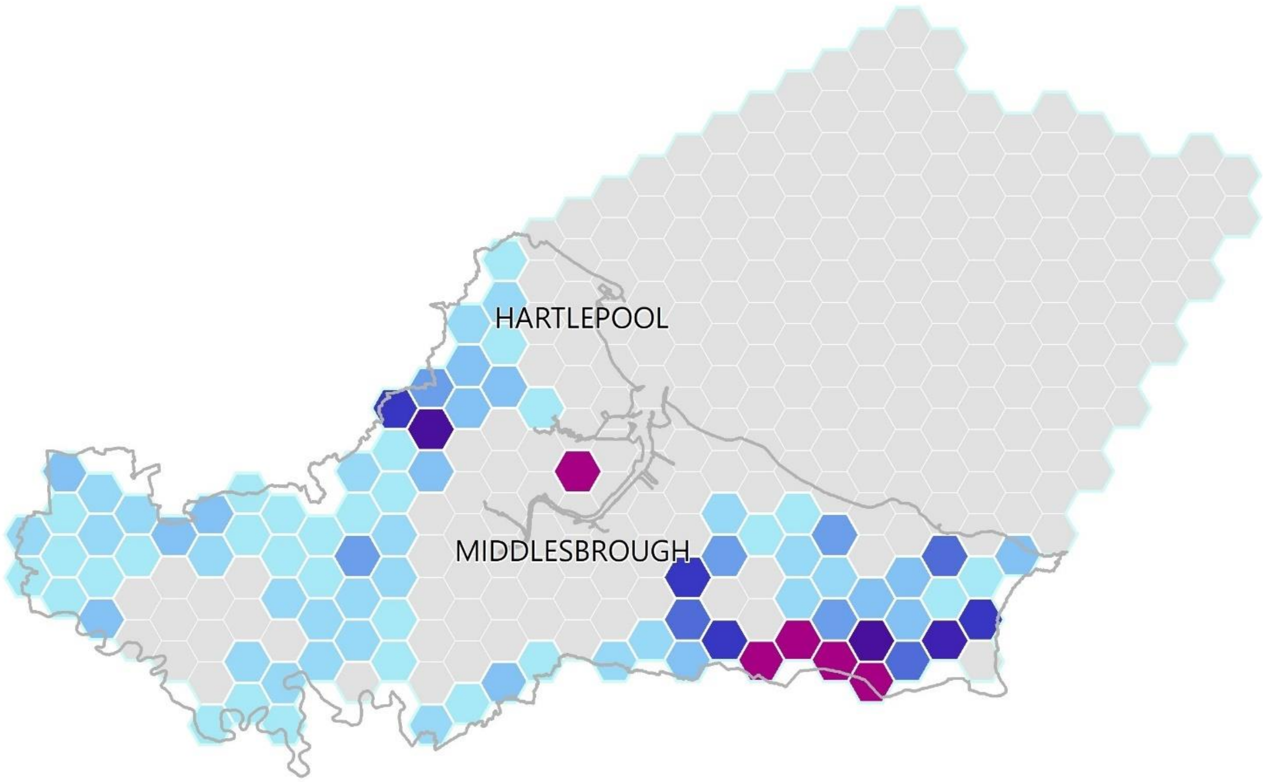
The measure for this indicator is the mean estimate of total abundance of invertebrates in topsoil (0–8cm depth soil core), estimated using Natural England and CEH's 'Mapping Natural Capital' project: Soil invertebrates (Henrys et al., 2012b).

This dataset is statistically extrapolated to a national level from CEH Countryside Survey data 2007. It does not include areas such as urban and littoral rock that are not surveyed in the Countryside Survey. Additionally, in some circumstances sample sizes for particular land parcel categories were insufficient to estimate mean values. The estimate is therefore only for land parcels with data, covering 52,528 ha. The weighted average (by size of land parcels) = 40.0.

To estimate this indicator we have used the original CEH dataset rather than the Natural Capital Atlas data as it is available at a more granular resolution ($1km^2$) than that mapped in the Atlas ($5km^2$). However, because we have used the same dataset as that used to map Soil Biota (ID: 60) in the Natural Capital Atlas we are still able to show how the indicator varies across the Tees Valley and how it compares nationally. Figure 12, taken from the Atlas, shows how the mean count varies across the Tees Valley at $5km^2$ resolution.

Using the Natural Capital Atlas data, the average of all hexagons with data across the whole of England is higher than the Tees Valley at 48.7. The modelled dataset shows that higher densities of soil invertebrates tend to be found in semi-natural, less intensively managed habitats such as woodland, acid grassland and dwarf shrub heath (Henrys et al., 2012). These habitats are primarily situated in the south east of the Tees Valley where it joins with the North York Moors.

Figure 12 Soil biota



Hexagon values: 11 – 80; Outliers 80 – 183

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021. Contains data supplied by © NERC – Centre for Ecology & Hydrology.

3.2.4 Species composition

The aspects of asset quality assessed for species composition are important in supporting the following ecosystem services: fish, marine products and game; timber and other materials; pollination; thriving wildlife; pest & disease control and cultural services. The species composition of soil is important for all ecosystem services dependent on soil processes.

In this Account we have not included any asset quality indicators under species composition. However, both soil invertebrate abundance and nectar plant diversity for bees are also relevant indicators of species composition.

3.2.5 Vegetation

The aspects of asset quality assessed for vegetation are important in supporting the following ecosystem services: fish, marine products and game; timber and other materials; clean water; clean air; erosion control; flood protection; thriving wildlife; climate regulation and cultural services.

Presence and frequency of pollinator food plants

CEH states that “Pollinators and pollination are important for both food production and wild flowers. Crops such as apples and field beans particularly require wild pollinators. Wild flowers make a significant contribution to cultural ecosystem services.” (CEH and Natural England, 2016) This indicator is also relevant for species composition.

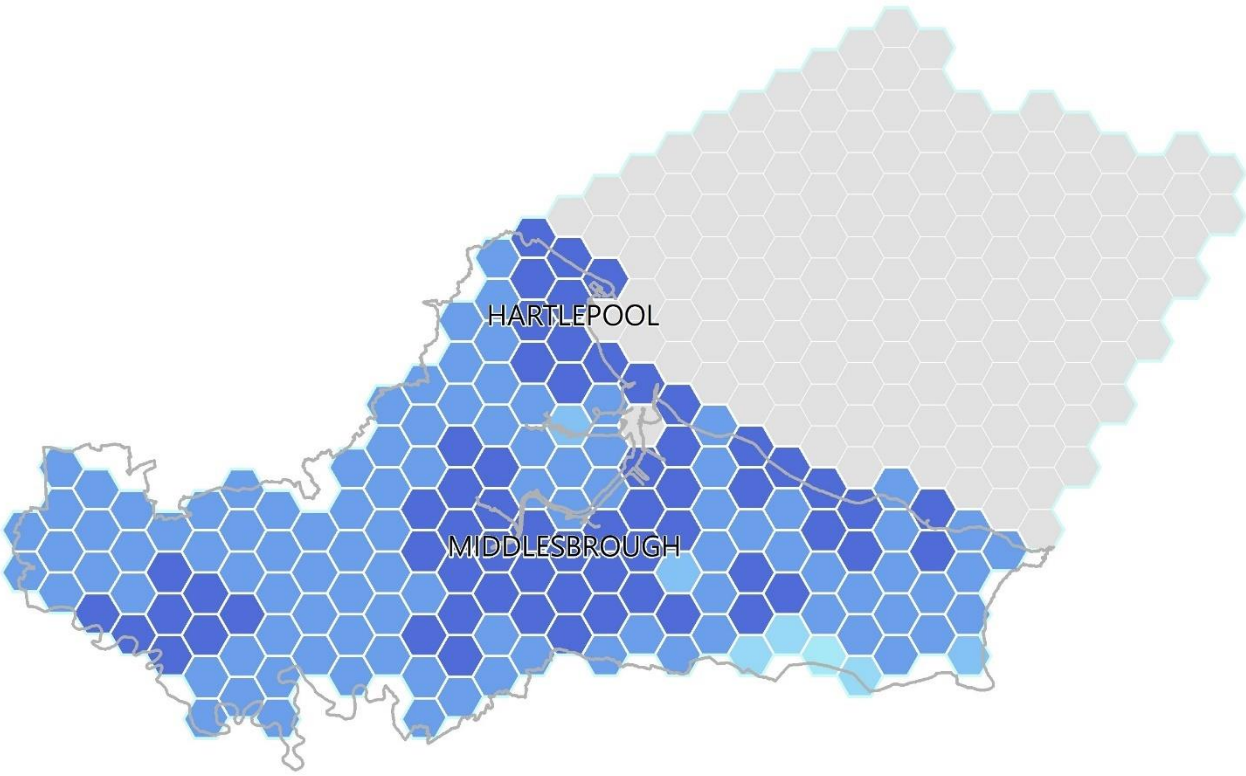
The measure for this indicator is the mean estimate of number of nectar plant species for bees (per 2×2m plot), estimated using Natural England and CEH’s ‘Mapping Natural Capital’ project: Nectar plant diversity for bees (Maskell et al., 2016).

This dataset is statistically extrapolated to a national level from CEH Countryside Survey data 2007. It does not include areas such as urban and littoral rock that are not surveyed in the Countryside Survey. The estimate is therefore only for land parcels with data, covering 52,528 ha. The weighted average = 4.2.

To estimate this indicator we have used the original CEH dataset rather than the Natural Capital Atlas data as it is available at a more granular resolution (1km2) than that mapped in the Atlas (5km2). However, because we have used the same dataset as that used to map Presence & Frequency of Pollinator Food Plants (ID: 62) in the Natural Capital Atlas we are still able to show how the indicator varies across the Tees Valley and how it compares nationally. Figure 13, taken from the Atlas, shows how the mean count varies across the Tees Valley at 5km2 resolution.

Using the Natural Capital Atlas data, the average of all hexagons with data across the whole of England is higher than the Tees Valley at 5.0. Figure 13 shows that values do not vary significantly across the whole of the Tees Valley.

Figure 13 Presence & Frequency of Pollinator Food Plants



Hexagon values: 0.55 – 6.12; Outliers 6.12 – 10.69

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021. Contains data supplied by © NERC – Centre for Ecology & Hydrology.

3.2.6 Cultural

These aspects of asset quality are important in supporting cultural ecosystem services.

Favourable Condition of Sites of Special Scientific Interest (SSSIs)

SSSIs are designated for both geological and biological features. Biodiversity is an important factor influencing the delivery of cultural services. A natural habitat with high species richness has the potential to offer valuable aesthetic, recreational or educational services. The presence of rare or flagship species (such as the harbour seals that breed in the Tees Estuary) or rare geological features is also important and may generate revenue for the local economy through tourism. Roughly 7% of the Tees Valley is designated as SSSI.

This indicator is also relevant for vegetation (favourable condition of SSSIs for biodiversity, is a proxy for appropriate vegetation composition and structure for other ecosystem services).

This indicator is measured using the percentage of SSSI area with 'favourable' condition status, estimated using Natural England's SSSI Units dataset (Natural England, 2019).

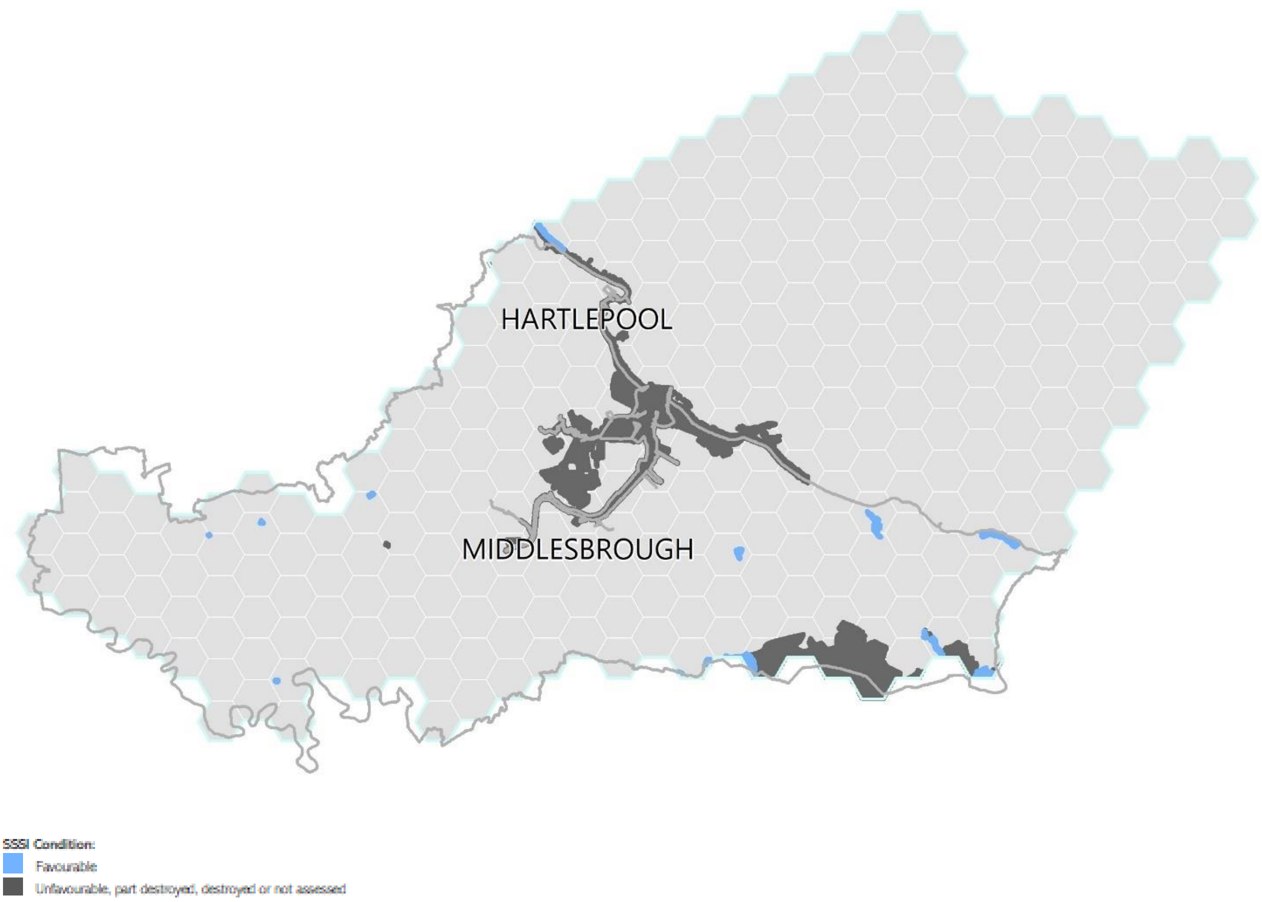
Using the Natural Capital Atlas data, 5,168 ha (7%) of the Tees Valley is designated as SSSI. Of this, 694 ha is categorised as favourable. However, in 2019, seven smaller SSSIs were merged into one expanded SSSI, the Teesmouth and Cleveland Coast, which covers almost 3,000ha. Because of this, categorisation data for this SSSI is not available and, as such, is blank in the SSSI category in the Atlas data.

Categorisation data is available for the previous SSSIs in Table 10 of the Teesmouth and Cleveland Coast SSSI notification document (Natural England, 2018). This reports that 1,954 ha was categorised as favourable. Combining this with the 694 ha, gives a total area of favourable SSSIs of 2,648 ha. 51% of SSSI area is therefore categorised as favourable (= 2,648/5,168).

Using Natural Capital Atlas data for SSSIs nationally, roughly 39% of SSSI area is favourable. SSSIs in the Tees Valley therefore compare favourably with the national average. Figure 14 below shows all SSSIs by whether they are in favourable condition or not. However, as noted above, due to the merging of SSSIs, the Teesmouth and Cleveland Coast SSSI around the Tees Estuary, which covers almost 3,000ha is categorised as not assessed despite two-thirds of it being in favourable condition. The largest area of SSSI categorised as unfavourable is the parts of the North York Moors (to the south east) which are situated within the Tees Estuary boundary. These are categorised as ‘Unfavourable recovering’.

Note: To make small areas of SSSI visible, all areas have been mapped with a thick border. This means areas may appear larger on this map than they are in reality.

Figure 14 Favourable condition of SSSIs



Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021. Contains Ordnance Survey data © Crown copyright and database right [2020].

Public Rights of Way

Public Rights of Way (PRoW) facilitate the delivery of cultural services in habitats that would otherwise be inaccessible to most.

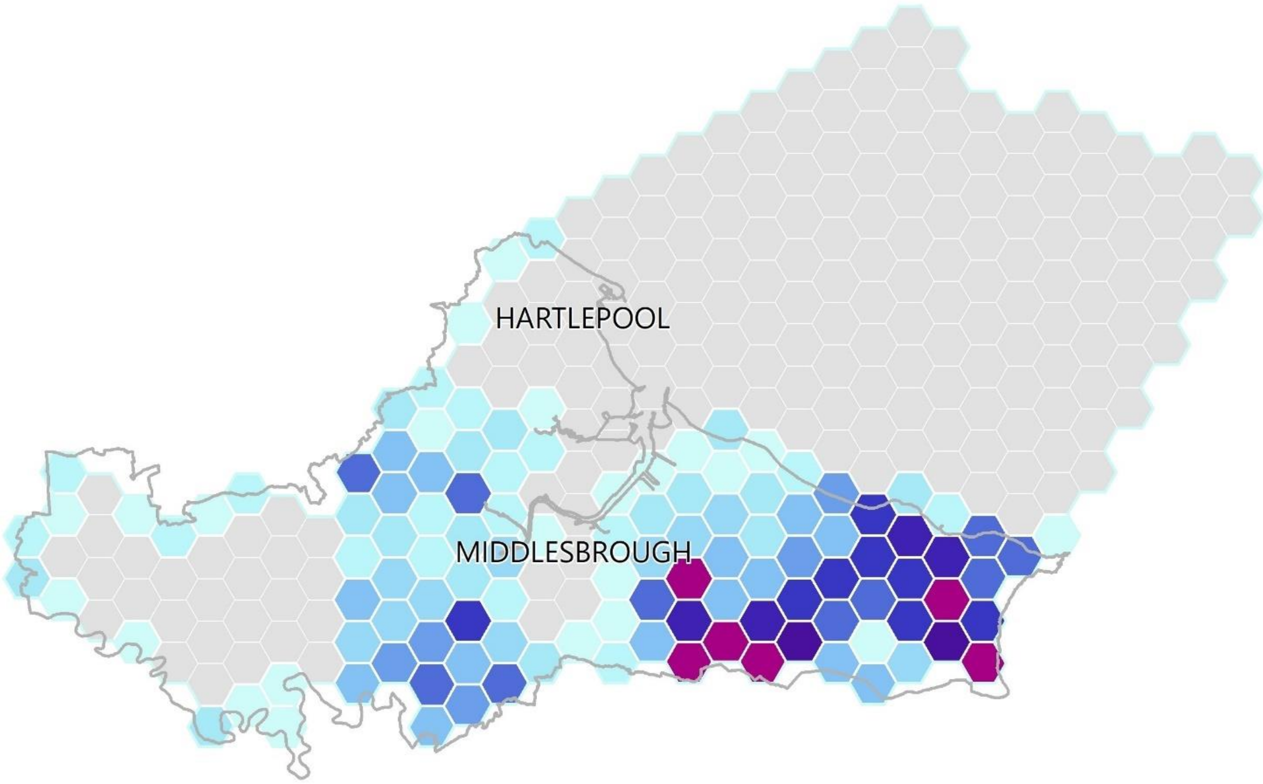
This indicator is measured using the length of Public Rights of Way (km) per hectare, estimated by combining open Local Authority datasets (Redcar and Cleveland, 2015 & Stockton-on-Tees, 2015). Note, for small areas it is difficult to differentiate between no data and absence of PRoW, therefore all gaps are being treated as no data (grey hexagons in Figure 15). The estimate therefore only applies to the proportion of land hexagons with data.

Using the Natural Capital Atlas data, we estimate there is 616 km of PRoW across the Tees Valley. Data is available for 69% of land hexagons, which represents 51,617 ha. This indicator is estimated by dividing the total length of PRoW by this area. The length of PRoW per hectare is therefore 0.012 km/ha (= 616/51,617). Figure 15 below shows the extent of PRoW across the Tees Valley.

Applying the same approach to the national data by comparing total PRoW length with total area of land hexagons with PRoW data, the national average is 0.014 km/ha. Tees

Valley is therefore very similar to the national average. The majority of PRoW is situated in the south east, with several hexagons in this area having very high ('outlier') lengths.

Figure 15 Public Rights of Way



Hexagon values: 0 – 13.61 km; Outliers 13.61 – 46.31 km

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021, using data derived from multiple sources, directed from the rowmaps website: www.rowmaps.com. All datasets used have open licenses (terms equivalent to OS Opendata License or Open Government License).

Designated historic environment assets (World Heritage Sites, Scheduled monuments (% at risk), Historic Parks & Gardens, Listed Buildings, Conservation Area)

Landscapes often contain designated heritage assets and boundary features that have remained in place for centuries and accrue tremendous historical value.

This indicator is measured using:

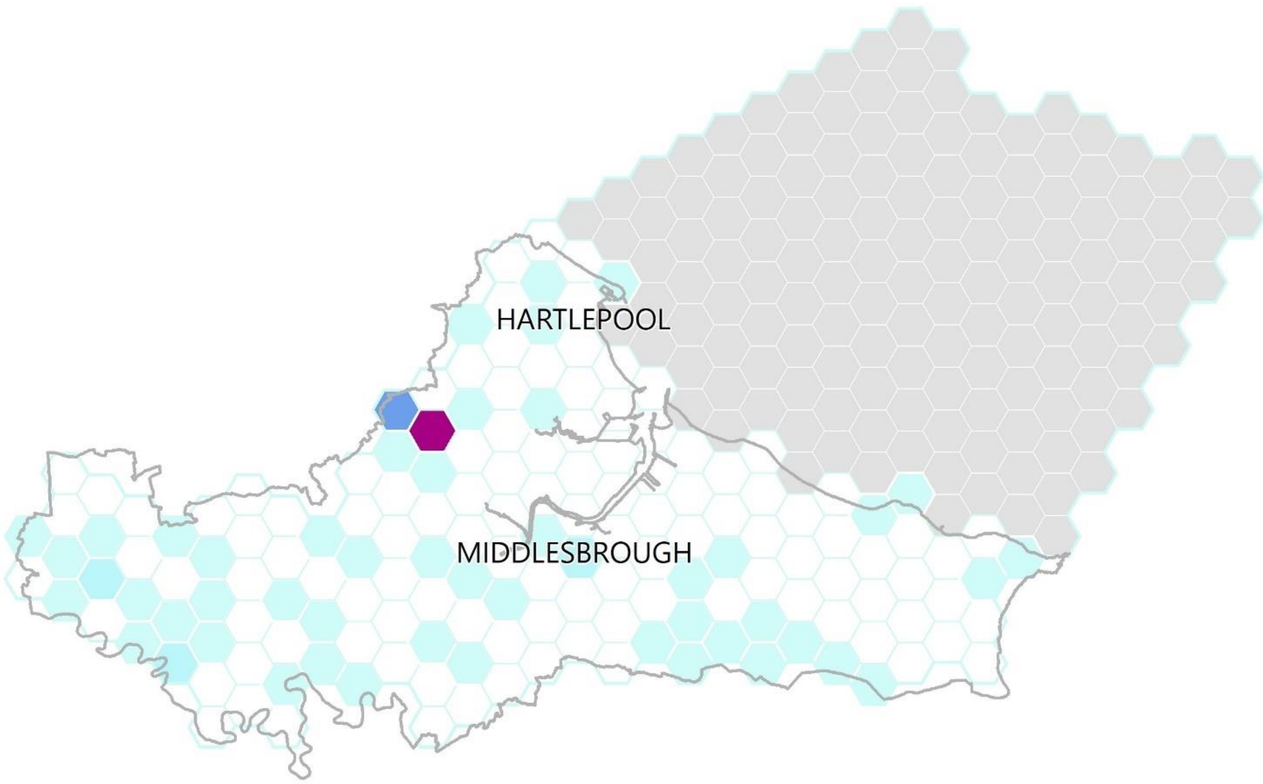
- the area of designated historic environment assets; and
- the total area of Scheduled Monuments at Risk.

Area of designated historic environment assets:

This measure is the area of designated historic environment assets (world heritage sites, scheduled monuments, parks and gardens, battlefields) mapped using Historic England's designated sites datasets (Historic England, 2018a);

Using the Natural Capital Atlas data, we estimate the total size of designated heritage assets to be 535ha. Figure 16 shows where they are situated, with the main area of heritage assets being Wynyard Hall and Wynyard Park (a large country house and surrounding Estate).

Figure 16 Designated historic environment assets



Hexagon values: 0 – 1.38 km^2; Outliers 1.38 – 5 km^2

Map sourced from Tees Valley Natural Capital Atlas (Lear et al. 2021). © Natural England 2021, using © Historic England [2020] data. Contains Ordnance Survey data © Crown copyright and database right [2020].

Scheduled Monuments at Risk (SMaR):

The importance of the historic environment in the provision of cultural ecosystem services was also represented through the inclusion of Scheduled Monuments at Risk data. Historic England record information on the extents of all monuments and attribute a risk level to each, based on its sensitivity to anthropogenic and environmental pressures such as ploughing, erosion and tree growth.

This indicator measure is the total area of Scheduled Monuments at Risk, across all risk categories, in the Tees Valley, estimated using Historic England's Scheduled Monuments at Risk data (Historic England, 2018b).

There are 72 locations in Historic England's Scheduled Monuments at Risk data, covering a total of 148ha. Table 12 shows the total area of locations in each classification. Of the total area 28% is classified as Vulnerable and 15% as At Risk.

Nationally, there are 2,090 archaeology entries on the 2020 Heritage at Risk Register (Historic England, 2018b). The Tees Valley therefore represents 3% of locations.

Table 12 Scheduled Monuments at Risk (hectares)

Scheduled Monuments at Risk Classification	Hectares (ha)	% of total SMaR area
Area At Risk	21.772	15%
Area Vulnerable	41.843	28%
Area Low/Not at Risk	82.881	56%
Area Unclassified	1.764	1%
Total SMaR Area	148.260	100%

4 Ecosystem services (physical flows)

This section provides estimates of the ecosystem service flows in the Tees Valley, as well as the methodology followed for each service.

The ecosystem services provided by natural capital in the Tees Valley are listed in Table 13 with quantification, where possible. We have not included significance ratings for services that we were not able to quantify. In our exercise respondents found it difficult to differentiate between ratings for ecosystem services and their benefits. We therefore have only included ratings for the final benefits, as shown in Table 24.

As noted in Section 2.2, there are important ecosystem services which we are unable to quantify. Where possible, we include information on quantities instead where they provide a reasonable proxy for the service, such as cropped area (these are written in italics in Table 13). We also provide related information that is available where this provides some additional context on the service.

Table 13 Ecosystem services provided by natural capital in the Tees Valley and quantification where possible for each service

Ecosystem service (common name)	**Indicator**	**Quantity** where available
Timber and other materials	Sales of wood and wood products (tonnes/year)	
Fish, marine products & game	Fish and marine products landed (tonnes)	1,500
Livestock	*Number of cattle, sheep and pigs*	*130,000*
Crops	*Cropped area (ha)*	*21,000*
Water supply	Quantity abstracted for public water supply	
Clean water		
Clean air	*Annual mean concentration of $PM_{2.5}$ at AURN network monitors ($\mu g/m^3$)*	*7-10*
Pollution regulation	PM2.5 removed by woodland (tonnes/year)	28
Erosion control		
Flood protection		
Pollination		
Pest and disease control		
Thriving wildlife		
Climate regulation	Carbon sequestration, t CO_2 equiv/yr Emission (arable & horticulture) Sequestration (other habitats)	(~157,000) ~84,000
Cultural - Experiential and physical use	Number of recreational visits (million/year)	25
Cultural appreciation of nature		
Cultural - Scientific and educational use		

4.1 Ecosystem services we have estimated

This section includes information on the services which we were able to provide estimates for. We also include those services for which a proxy indicator has been identified (values in italics). Where possible, we compare the Tees Valley estimates with national estimates. To provide some context to these comparisons, the Tees Valley makes up about 0.5% of England's total land area and 0.3% of total UK land area.

4.1.1 Fish and marine products (capture) and Game

This indicator is the quantity of fish and marine products landed at Tees Valley ports.

Ideally, we would use the quantity of fish and marine products caught within the marine area we have mapped in the Tees Natural Capital Atlas (up to 12 nautical miles from the coastline). This is likely to be less than the quantity landed at Tees Valley ports as fish landed at specific ports will generally have been caught over a wide area. We cannot correct for this since data is not available on the locations where fish are caught – just where they are landed. The figure is likely therefore to be an over-estimate

Data on landings by port are available from the UK sea fisheries annual statistics report (Elliott et al., 2019). Chapter 3, Table 3.14 'Landings into UK ports by UK vessels' provides estimates of all species landings at all UK ports for the last 5 years (2014 to 2018). Landings can vary widely from year to year, so we have based 'current flow' on the average for 2014 to 2018, as shown in Table 14.

Table 14 Landings into Hartlepool port by UK Vessels (2014 to 2018)

	Quantity ('000 tonnes)					
Port	2014	2015	2016	2017	2018	5 year average
Hartlepool	1.0	1.0	0.9	1.7	2.8	1.5

Hartlepool is identified as the only port in the TVCA area with commercial fish landings. We therefore estimate current landings for the Tees Valley as 1,500 tonnes (2014 to 2018 average for Hartlepool).

Total landings by UK vessels at all UK ports is 450,000 tonnes. Landings at Hartlepool therefore account for 0.3% of total UK landings (figures disaggregated for England are not available).

We understand that recreational bait collection occurs at points around the estuary, but it is not possible to quantify levels so we have not attempted to include it in our analysis.

4.1.2 Livestock

This indicator is the number of cattle, sheep and pigs on agricultural holdings within the Tees Valley.

Livestock numbers are used as a proxy for the ecosystem service. Annual flow e.g. number of livestock reared would provide a better indicator, but this data is not published by Defra at Local Authority level.

The number of livestock are estimated using Defra, Structure of the agricultural industry in England and the UK (Defra, 2018). Current flow is based on figures for 2016.

Livestock numbers for TVCA area are the total for Darlington, Hartlepool, South Teesside[5] and Stockton-On-Tees, as shown in Table 15.

Table 15 Livestock numbers by Local Authority (2016)

	Livestock			
Local Authority	Cattle	Sheep	Pigs	Total
Darlington	10,406	23,049	10,315	43,770
Hartlepool	3,284	5,627	2,391	11,302
South Teesside	8,964	17,726	28,577	55,267
Stockton-on-Tees	4,027	8,018	6,326	18,371
Total	26,681	54,420	47,609	128,710

Total number of livestock in the Tees Valley is therefore 130,000 (rounded to nearest 5,000).

Nationally, there is 24.4 million livestock across the whole of England (Defra, 2018). The Tees Valley therefore accounts for about 0.5% of the England total.

[5] South Teesside is an old Local Authority district still used in Defra crop and livestock statistics. It covers Middlesbrough, Redcar and Cleveland.

4.1.3 Crops

This indicator is the cropped area for cereals, arable crops (excl cereals) and fruit and vegetables within the Tees Valley.

Cropped area is used as a proxy for the ecosystem service. Annual flow e.g. tonnes harvested would provide a better indicator, but this is not published by Defra at Local Authority level.

Cropped area is estimated using *Defra, Structure of the agricultural industry in England and the UK* (Defra, 2018). Current flow is based on figures for 2016.

Cropped area for the Tees Valley is the total of cereals, arable crops (excl cereals) and fruit and vegetables for Darlington, Hartlepool, South Teesside[6] and Stockton-On-Tees, is shown in Table 16.

Table 16 Cropped area by Local Authority (2016)

	Cropped area (ha)			
Local Authority	Cereals	Arable crops (excl cereals)	Fruit and vegetables	Total
Darlington	6,402	1,748		8,150
Hartlepool	2,178	694	0	2,873
South Teesside	4,314	1,321	5	5,640
Stockton-on-Tees	3,808	879		4,687
Total	16,703	4,643	5	21,350

The total cropped area for the Tees Valley is therefore 21,000 ha (rounded to the nearest 1,000 ha). This represents 28% of the total area of the Tees Valley and just under 50% of total enclosed farmland (Table 10).

[6] South Teesside is an old Local Authority district still used in Defra crop and livestock statistics. It covers Middlesbrough, Redcar and Cleveland.

Nationally, there is almost 4 million hectares cropped area across the whole of England. The Tees Valley therefore accounts for about 0.5% of the national cropped area. Nationally, about 30% of England's total land (13 million ha) area is cropped so the Tees Valley is similar to the national picture (Defra, 2018).

4.1.4 Clean air

This indicator is the annual mean concentration of PM2.5 at Defra Automatic Urban and Rural Network (AURN) monitors (µg/m^3)

AURN estimates provide an indication of air quality at a limited number of locations within the Tees Valley. AURN monitoring stations are situated in areas that are expected to have higher pollution levels. These estimates are therefore likely to be atypical of air pollution levels across the Tees Valley. Estimates should therefore be interpreted as a proxy indicator of air quality across the Tees Valley, rather than an estimate of air quality. Further work is required to assess whether natural capital accounts can be improved by including air quality data from Defra. Alternatively, it may be more appropriate to incorporate this estimate as an asset quality indicator.

Hourly measurements of PM2.5 concentration are available for 62 monitoring sites across England, as well as annual statistics (Defra, 2019a). The Tees Valley has three PM2.5 monitors as part of the national AURN network – Middlesbrough, Stockton-on-Tees A1305 and Stockton-on-Tees Eaglescliffe. We have used the hourly measurements to estimate annual means for each of the 3 sites in the Tees Valley for 2017 to 2019.

Table 17 Annual mean concentration of PM2.5

	Annual mean concentration of PM2.5 (µg/m^3)		
Site	2017	2018	2019
Middlesbrough	7.5	8.9	10.3
Stockton-on-Tees A1305	8.1	9.4	8.1
Stockton-on-Tees Eaglescliffe	8.5	10.1	8.3

As this data is available at only 3 sites, taking an average across them would not provide a good indication of air quality across the Tees Valley. We instead present the results as a range, 7 to 10 µg/m^3. However, as noted above, these estimates are taken from sites that are likely to be atypical of air quality across the Tees Valley so even this range should be interpreted as a proxy indicator of air quality across the Tees Valley, not an estimate of air quality.

As context, the average annual mean across all 62 PM2.5 monitoring sites in 2019 was 10 µg/m^3, within a range 8 to 15 µg/m^3. Measurements at the 3 Tees Valley sites are therefore towards the bottom end of the national measurements.

4.1.5 Climate regulation

This indicator is the net carbon emissions tonnes of carbon dioxide equivalent (CO_2e) from natural capital in the Tees Valley. As habitats vary between being a net sequesterer or emitter we present separate figures for sequestration and emission.

The emission factors used to inform GHG flux calculations are based on median values[7] reported in 'Accounting for Nature' (Bolt et al., 2017), the RSPB's natural capital account of their estate in England, which used values derived from a review of scientific literature – see Table 18 below, which also includes estimates of carbon emission/sequestration by LCM habitat class in the Tees Valley.

As a comparator, a supplementary estimate for agricultural GHG emissions has also been obtained from Exeter University's NEVO tool (Day et al, 2019a).

Estimates of emissions from agriculture in Bolt et al., and NEVO include emissions from machinery. Other habitats do not include emissions from management measures. Eventually, these should also be incorporated e.g. emissions from forest harvesting.

Our estimate and the NEVO estimates are based on CO_2 equivalents e.g it takes account of the equivalent warming effect of other greenhouse gases. Nationally more than 80% of agricultural greenhouse gas emissions (in CO_2 equivalents) are from Methane and Nitrous Oxide (ONS, 2018). Note that Local Authority emissions estimates provided by BEIS (BEIS, 2019a) are much lower because they *only* cover CO_2.

Table 18 Carbon Emissions by LCM Habitat Class

Broad Habitat	LCM habitat class	C Emission by habitat ($tCO_2e/ha/yr$)	TVCA Area (ha)	C Emission by habitat (tCO_2e/yr)
Woodlands	1 Broadleaved woodland	-10.71	4,123	- 44,159
	2 Coniferous woodland	-17.51	666	- 11,668

[7] Actual sequestration/emission rates will vary widely by condition, location etc. For example, the value for "Bog" in Table 18 is for intact blanket bog. If the bog is damaged it will emit – not sequester. See for example Dickie, I., Royle, D., & Neupauer, S. (2019). *Testing a natural capital approach on Scottish Natural Heritage land* (Scottish Natural Heritage Research Report No. 1144.).

Enclosed farmland	3 Arable and horticulture	5.39	29,128	156,999
	4 Improved grassland	-1.55	15,333	- 23,767
Semi-natural grassland	5 Neutral grassland	-1.55	1,359	- 2,107
	6 Calcareous grassland	-1.55	13	- 21
	7 Acid grassland	-1.61	37	- 60
Open water, wetlands, floodplains	8 Fen, marsh and swamp	-3.91	157	- 615
	11 Bog	-1.7	-	-
	14 Freshwater	6.86	574	3,936
Mountains, moorlands, heaths	9 Heather	-3.45	8	- 27
	10 Heather grassland	-3.45	147	- 507
	12 Inland rock		105	-
Marine	13 Salt water		847	-
	17 Littoral rock		191	-
	18 Littoral sediment	-2.34	975	- 2,281
Coastal margins	15 Supra-littoral rock		-	-
	16 Supra-littoral sediment	-1.14	322	- 367
	19 Saltmarsh	-4.2	537	- 2,255
Urban	20 Urban		8,116	-
	21 Suburban		12,481	-

Total (net emissions)			73,101
Of which: ***Total emissions (arable and horticulture)***			*156,999*
Total sequestration (other habitats)			*- 83,898*

Accounting for all habitat types, we therefore estimate a net emission of ~73,000 tonnes of CO_2 equivalent per year.

Excluding arable and horticultural land, we estimate that gross carbon sequestration by natural habitats is 84,000 tonnes of CO_2 equivalent per year. ONS's UK natural capital accounts (ONS, 2019a) report that gross carbon sequestration from UK natural habitats was 28.0 million tonnes in 2017. Gross carbon sequestration in the Tees Valley accounts for about 0.3% of this figure.

Emissions from arable and horticultural land are estimated as 157,000 tonnes of CO_2 equivalent per year. Although not a direct comparison, ONS reports total UK emissions from agriculture of 47.7 million tonnes CO_2 equivalent in 2018 (ONS, 2020). Again, the Tees Valley estimate accounts for 0.3% of this total. Total UK GHG emissions across all sectors is estimated at 563.9 million tonnes CO_2 equivalent in 2018 (ONS, 2020).

As comparison, the NEVO estimate of emissions from agriculture of (~128,000 tonnes) is broadly similar to our estimate (~ 157,000 tonnes). We therefore have moderate confidence in our estimate.

4.1.6 Air pollution regulation

This indicator is the amount of $PM_{2.5}$ removed by woodland (tonnes/year).

Estimates are based on the 'Pollution Removal by Vegetation' tool developed by CEH/eftec (Eftec and CEH, 2019a), based on work by Jones et al. (2019). The tool estimates the quantity and value of pollution removal by vegetation for each Local Authority. Values vary by factors including pollution levels, population and area of woodland (Eftec and CEH, 2019b).

The values in the tool concentrate only on PM2.5 removal by woodland as PM2.5 is the most damaging pollutant and trees are the most efficient habitat at removing pollutants. The figure is therefore likely an under-estimate of the total amount of air pollution removal by all natural capital. For example, according to Jones et al., Table 7, $PM_{2.5}$ removal accounts for 71% of the total benefits of pollution removal from $PM_{2.5}$, SO_2, NO_2 and O_3 in Britain as a whole.

The total estimate of air pollution removal for the Tees Valley is the total of the 5 Local Authorities, as shown in Table 19.

Table 19 PM2.5 removed by woodland (kg/year), TVCA area

Local Authority	Area of woodland (ha)	PM2.5 removed by woodland (kg/year)	PM2.5 removal rate per ha woodland (kg/ha year)	Asset value of PM2.5 removal (£ million, 2019 prices)	Asset value of PM2.5 removal per ha (£/ha, 2019 prices)
Darlington	642	3,536	5.5	41.3	64,402
Hartlepool	387	2,620	6.8	32.4	83,759
Middlesbrough	119	607	5.1	36.3	305,438
Redcar and Cleveland	2,643	15,264	5.8	47.9	18,124
Stockton-on-Tees	937	5,586	6	77.2	82,405
TVCA area total	4,728	27,613		235.1	

We therefore estimate that the total PM2.5 removed by woodland is 28 tonnes per year. ONS (2019a) estimated that all UK vegetation removed 1.3 million tonnes of pollutants in 2017, of which 1.7% was PM2.5, 22,000 tonnes. The Tees Valley figure is therefore 0.1% of the total UK estimate of PM2.5 removal.

Additional instructions on how to use the tool are provided in Appendix E.

4.1.7 Cultural services – physical and experiential use

This indicator is the number of recreational visits to all greenspace within the Tees Valley.

The number of visits is estimated using the Outdoor Recreation Valuation Tool (Day and Smith, 2018). This provides a consistent source of estimates of recreational visits made by adult residents of England, which can be broken down at Local Authority level. Recreational visits include all kinds of activities that take place in nature including walking the dog, jogging, cycling, riding etc.

The Outdoor Recreation Valuation Tool (ORVal) uses data from the Monitor of Engagement with the Natural Environment (Natural England, n.d.b.); the national survey on people and the natural environment[8]. Predictions of visits to a greenspace are adjusted according to a range of factors, including the socioeconomic characteristics of people, attributes of a greenspace and the availability and qualities of alternative greenspaces.

ORVal estimates are broken down by visits to paths, parks and beaches. Using ORVal, we estimate that there are 266.6km of paths, 90 million m^2 of parks and 4 beaches.

The numbers of recreational visits by greenspace type are shown in Table 20. Estimates of visits by different socio-economic groups are also available from ORVal.

Table 20 Recreational visit estimates from ORVAL, TVCA area

Type of greenspace	Paths	Parks	Beaches
TVCA area total visits ('000/yr)	3,100	20,500	1,100

The total number of recreational visits to all greenspace is therefore estimated to be 25 million per year (rounded to nearest million).

Using ORVal, we estimate that there were 2,500 million total recreational visits to greenspace in England. Visits to sites in the Tees Valley represent 1% of total visits in England.

Additional instructions on how to use the tool are provided in Appendix E.

4.2 Ecosystem services for which indicators are available

This section includes information on the services which we were able to identify indicators for but, without collecting bespoke local information e.g. from landowners, we were unable to identify estimates for.

4.2.1 Timber and other materials

The ideal indicator for this service is the sales of timber and wood products (tonnes/year).

However, national data for stumpage value or timber harvested/sold, broken down by Local Authority is not available.

[8] The MENE survey has now been replaced by the People and Nature Survey but this has not been incorporated into ORVal estimates.

Data is available at national and country level from Forest Research. According to ‘Wood production (roundwood removals)’ in 2019, wood production for the whole of England was 2,125 thousand green tonnes softwood and 763 thousand green tonnes hardwood (Forest Research, 2019).

Forest Research also publishes data by region on the number of sawmills and softwood production. Data for the North East Region shows softwood production of 330,000 m^3 by 10 mills in the North East in 2018. This compares with total England softwood production of 1,122,000 m^3 by 83 sawmills (Forest Research, 2019).

We do have information on the area of woodland in the Tees Valley but this is not a good proxy of timber production without information on the extent of this woodland used for forestry.

4.2.2 Water supply

The ideal indicator for water supply is the quantity abstracted from water sources within the Tees Valley for public water supply (m^3).

However, this data is not currently available at Local Authority level.

The Environment Agency publish water abstraction data by EA charge region in ‘Estimated abstractions from all sources except tidal by purpose and EA regional charge area: 2000 to 2017’ (EA, 2019b).

Abstractions for the North East charge region in 2017 were 743 (public water supply) and 1,987 (total) million cubic metres. For England, in 2017 abstractions were 5,320 (public water supply) and 10,395 (total) million cubic metres.

4.2.3 Noise regulation

The ideal indicator for this service would be the number of properties benefitting from noise reduction due to vegetation of at least 1 decibel (dB).

However, estimates of noise reduction by vegetation at Local Authority level are not available and would require specialist input to develop. They are therefore outside the scope of this technical report.

Methods for the assessment of noise reduction and associated benefits are under development. Kuyer, Cryle et al (2018) proposed a range of methodologies and estimates. Uncertainties include the data used to estimate the extent of relevant vegetation and whether to include all buildings with noise reduction or only those with background noise levels >60dB.

Using the methodology developed by Kuyer, Cryle et al. (2018), ONS (2019a) estimates that 143,000 buildings in England within noise bands above 60dB benefited from noise reduction due to vegetation in 2017.

4.3 Ecosystem services currently without indicators

4.3.1 Clean water, Erosion control, Flood protection, Pollination, Thriving Wildlife, Pest and disease control

Indicators for these ecosystem services are not included because of the difficulty of identifying appropriate *single* indicators and the lack of national data sets – as in Sunderland et al. (2019).

Information on water quality is included via ecosystem asset quality indicators for surface and ground water (Sections 3.2.1 and 3.2.2) that could be used as indicators of the ecosystem services.

4.3.2 Minerals, Fossil Fuels, Renewable Energy

ONS (2019a) includes information on minerals, fossil fuels and renewable energy in the UK natural capital accounts 2019.

These provisioning services are not included in these local natural capital accounts since they are generally well known and accounted for in the market economy.

5 Benefits and values (monetary flows)

Society values natural capital for the enjoyment people gain from it and the benefits it provides. We have assessed the significance of these benefits and where possible have estimated their monetary value. These results are summarised in Table 21 below.

The majority of benefits which we could value were from recreation, which were estimated as being of the order of £100 million per year. The next most significant were the health benefits associated with improved air quality, at about £8 million per year. We also estimate small benefits associated with fisheries, crops and livestock.

Additionally, we quantify the contribution natural capital assets make to sequestering carbon. Focussing only on those habitats that sequester carbon, we estimate a benefit of about £5.7 million in 2019. However, these benefits are outweighed by the emissions from arable and horticultural habitats. Overall, we estimate that net carbon emissions from natural capital assets in the Tees Valley have an annual social cost of around £5 million. The unit cost of carbon emissions represents the cost of other measures to remove the equivalent amount of carbon at that point in time. It is therefore scheduled to rise sharply over the next 50 years. If emissions remain at current levels the annual cost of these emissions would reach £26 million in 2075.

Benefits that we cannot value in monetary terms provide large additional benefits and some are highly significant. Those identified as most significant were water abstraction, flood protection, biodiversity and, contributions to physical and mental health. Other non-monetised benefits include timber, pollination services and other cultural benefits that people gain from nature, such as scientific and educational opportunities and cultural appreciation. The £100 million per year figure represents only those services that can be valued in money terms, not those that are most important. It is therefore a significant under-estimate of the true value of natural capital across the Tees Valley.

Overall, we estimate the monetary value of quantifiable benefits from natural capital in the Tees Valley to be in excess of £100 million per year with a natural capital asset value of almost £3 billion. There are benefits of ‘very large’ significance that we have not been able to value in monetary terms and suggest that, based on the level of significance placed on these non-monetised benefits, these are likely greater than the quantified values.

Further detail on each value and the method is provided throughout this chapter.

Table 21 The benefits and value of natural capital in the Tees Valley

Benefit	Significance (1 small to 3 large)	Indicator	Annual benefit	Asset value	Confidence in the values
Timber, hay and other materials	1	Timber and wood products, stumpage value			
Food	1	Net income from fisheries	£360,000	£11 million	●
	1	Resource rent from crop and livestock production	~ £0	~ £0	●
Clean and plentiful water	3	Value of water abstraction			
Clean air	3	Health benefits from PM2.5 removal	£8 million	£235 million	●
Protection from floods and other hazards	3	Value of flood protection benefits provided by natural capital			
Pollination and pest control	1	Value of pollination and pest and disease control			
Biodiversity	2				
Equable climate	3	Social cost of carbon emission (natural capital)	(£5 million)	(£395 million)	●
Cultural wellbeing	3	Social benefit of recreational visits (parks, beaches & paths)	£100 million	£3.0 billion	●
	3	Physical and mental health and other benefits			

Total quantified monetary benefits	**£103 million**	**£2.8 billion**
Significance of unquantified monetary benefits	**Very large**	

5.1 Benefits we can monetise

This section sets out the values of benefits we can monetise, including the method.

5.1.1 Fish and marine products

The value of this service is estimated using net profit from fish capture landed in the Tees Valley.

The use of net profit is different to crops and livestock (see Section 5.1.2 below), which we value using resource rent. However, we use net profit to be consistent with the approach used by ONS (2019a). As noted below, the limited evidence on resource rent for fish capture suggests estimates using the two approaches are similar.

ONS (2019a) estimates the value of fish capture using net profit per tonne (landed) estimates, provided by Seafish, for different marine species. However, these estimates are not publicly available on the Seafish website.

Net profit can be estimated based on ONS (2019a) which suggests average annual profit of £240/tonne (net profit of £324 million from 1.35 million tonnes).

Thornton et al. (2019, pg 50) follow a resource rent approach (see Section 5.1.2 below for further explanation of the resource rent approach). Their analysis suggests average resource rent of ~£240/tonne in 2016, and an average of ~ £180/tonne over the period 2012-2016 (2017 prices). This alternative estimate is therefore consistent with the ONS estimate.

Hartlepool is identified as the only port in the TVCA area with commercial fish landings. The value of fish landed is recorded as averaging £2.7 million (2014-2018) in the annual statistics report Table 3.14, (a) All species (Elliot et al., 2019). However, net profit (after deduction of costs) is much less. Average 2016 net profit for UK as a whole based on ONS (2019a) was £240/tonne. Given average landings of 1,500 tonnes (Section 4.1.1) this suggests net profit of around £360,000 per year (= 1,500 x £240).

Our confidence rating for this value is amber (+ or – 50%). We are reasonably confident on both the estimates of fish capture at Hartlepool and the value per tonne as these are both based on market data. However, without data on where the fish is captured it is likely that a proportion of the fish landed was caught outside of the marine area we assign to the Tees Valley and therefore the total value is likely an over-estimate.

5.1.2 Crops and livestock

The value of this service is estimated using the resource rent from crop and livestock production.

We estimate resource rent from crop and livestock production as recommended by ONS (2017b, p. 33). “In concept, the resource rent of an asset strips out the value-added, or annual return, accruing directly to the asset itself, … it is the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been taken into account…"

The principle behind this approach is that "valuation should aim to isolate the contribution of the ecosystem to the service received by users. Therefore valuation should exclude human inputs and produced capital." (ONS, 2017b).

However, the resource rent approach to the valuation of provisioning services has not been applied in all natural capital accounts. This approach to valuation of benefits in natural capital accounts was taken by Vivid Economics (2017) and White et al. (2015). In contrast, Dickie et al. (2018) and Day et al. (2019b) in the NEVO model, use gross margins instead with values up to £400/ha or more.

Data on farm incomes is collected annually in the farm business survey and reported by Defra (Defra, 2019b). Average farm income is broken down by cost centre – enabling income from diversification, agri-environment payments and the basic payment scheme to be separated out from agricultural income. Net farm income[9], all farm types, including income from agriculture *only,* provides the best estimate of resource rent. This was negative in 2016/17 and 2017/18 – with losses per farm of £15,800 and £3,400. Calculations based on the annual farm business survey are shown in Table 22. We assume a value of zero in this report.

[9] Definition available in 'Definitions used by the Farm Business Survey', pg 5, Defra (2016)

Table 22 Resource rent for crops and livestock production[10]

		Agriculture	
		2016/17	**2017/18**
Derivation of farm income measures:			
1	**Total Output**	**221,900**	**257,200**
2	Variable costs (b)	116,100	130,400
3 = 1 - 2	**Total Gross Margin**	**105,800**	**126,800**
4	Fixed costs	108,700	116,800
5 = 2 + 4	**Total Costs**	**224,900**	**247,200**
6	Profit/(loss) on sale of machinery, glasshouses and permanent crops (c)	400	400
7 = 1 – 5 + 6	**Farm Business Income (d)**	**-2,500**	**10,400**
8	Adjustment for unpaid manual labour (e)	27,200	28,100
9 = 7 - 8	**Farm Corporate Income (f)**	**-29,700**	**-17,700**
10	Interest payments on borrowing (net of interest received) (g)	5,100	5,500
11 = 9 + 10	**Farm Investment Income (h)**	**-24,600**	**-12,200**
Derivation of Net Farm Income:			
12	Director remuneration	1,800	1,900
13	Imputed rent (i)	23,800	25,800
14	Ownership charges	8,700	9,800
15	Unpaid labour of principal farmer and spouse	22,100	22,900
16=11+12-13+14+15	**Net Farm Income**	**-15,800**	**-3,400**

[10] All figures taken from Farm Accounts in England 2017/18, Table 5.23 (Defra, 2019b) except 'Net Farm Income', which has been calculated by Natural England as we exclude non-agriculture income

We rate the confidence rating for this benefit as red (within order of magnitude). We have had to use proxies for both crop and livestock production. Furthermore, as noted above, the resource rent approach is not widely agreed to be the appropriate methodology for estimating this benefit. Using another approach, such as gross margins, would give a higher value.

5.1.3 Clean air

This service is valued by estimating the health benefits from PM2.5 removed by woodland.

Values are based on the 'Pollution Removal by Vegetation' tool (Eftec and CEH, 2019a), developed to estimate the quantity and value of pollution removal by vegetation (see Section 4.1.6, air pollution removal above). As noted in Section 4.1.6, the tool only estimates PM2.5 removal by trees as the most damaging pollutant and most effective natural asset so the value is an under-estimate.

The average long-term annual health benefit in the Tees Valley is estimated to be £8 million per year, with an asset value of £235 million.

Values per year are not provided by the model as benefits are expected to reduce in the future as pollution levels fall (Jones et al., 2019). The annual benefit estimate has been calculated as the value that would result from constant annual benefits over 100 years (asset value/29.86). The annual value therefore represents the long-term average annual benefit rather than the current annual benefit. Additional instructions on how to use the tool are provided in Appendix E.

Our confidence in this value is rated as amber (+ or – 50%). The tool accounts for a range of factors at Local Authority level in estimating pollution removal so we are reasonably confident of the relevance of the specific estimates for the Tees Valley. However, as necessary with all tools, there are a range of limitations, such as a focus only on woodland and not accounting for types of trees or planting densities.

5.1.4 Carbon sequestration/emission from natural capital assets

This benefit is the social cost/benefit of carbon sequestration/emission from natural capital assets.

The cost/benefits of sequestration/emission (in tonnes of CO_2 equivalent) are valued at £68/tonne (2019) rising to £355 in 2075 (non-traded, central prices), as recommended by the Department for Business, Energy & Industrial Strategy (BEIS, 2019b)[11].

[11] Carbon prices taken from Table 3 of the supporting data tables

Accounting for all habitat types, we estimate a net emission of ~73,000 tonnes of CO_2 equivalent per year (Section 4.1.5). Applying the BEIS carbon prices to these emissions results in a net cost of around £5 million in 2019, gradually increasing to £26 million in 2075, as the value of carbon sequestration per tonne rises. This gives a negative asset value of £395 million (Appendix F).

If we only looked at habitats that sequester carbon, we estimate that gross carbon sequestration is 84,000 tonnes of CO_2 equivalent per year. Applying the above carbon prices, results in a benefit of £5.7 million in 2019, rising to £29.8 million in 2075, with an asset value of £455 million.

Although this figure is outweighed by the emissions from arable and horticultural habitats, resulting in the net emissions figure above, the gross sequestration value shows the potential that natural capital can have in delivering net zero. This is explored further in Section 7.

Our confidence rating for carbon sequestration/emissions is red (within order of magnitude). This reflects our confidence in the underlying evidence for estimating carbon sequestration.

5.1.5 Cultural wellbeing – recreation

This benefit is the social benefit of recreation/recreational visits (to parks, beaches & paths).

The benefit value has been estimated using ORVal (Day and Smith, 2018). The method is the same as followed to estimate the number of recreational visits, as described in Section 4.1.7 above. Additional instructions on how to use the tool are provided in Appendix E.

Using ORVal we estimated that there were 25 million recreational visits annually to greenspace in the Tees Valley. However, rather than estimate the value of these visits by multiplying it by the average value of a visit, ORVal estimates value considering characteristics specific to the sites.

ORVal estimates welfare values[12] for an existing site by "calculating how much each individual's welfare would fall if they were no longer able to access that site and then converting that welfare quantity into an equivalent monetary amount" (Day et al., 2019c). This welfare value is estimated by considering the attributes of the site, substitutes and the distance travelled by visitors. By applying a cost of getting to the site, including both the monetary cost of travel and travel time, it is possible to estimate the value that a visitor

[12] "By 'welfare value' we mean a figure describing the monetary equivalent of the welfare enjoyed by individuals as a result of having access to a greenspace. In economics this welfare value is often alternatively called an 'economic value' or a 'willingness to pay'" (Day et al., 2019c).

places on the visit to that site. By aggregating across the adult population, the tool estimates the welfare value of all visits to that site. The total Tees Valley value is the aggregated value of each site in the Tees Valley.

The results are shown in Table 23, below, broken down by greenspace type. Estimates of visits by different socio-economic groups are also available from ORVal.

Table 23 Welfare value of recreational visits from ORVAL, TVCA Area

Type of greenspace	Paths	Parks	Beaches
Welfare value of visits (£ million/yr), TVCA area	12.7	84.0	4.6

We therefore estimate the annual benefit to be £101.3 million per year (rounded to £100 million), with an asset value equal to £3.0 billion.

We have assessed our confidence for recreation benefits as red (within order of magnitude). The authors of the model advise that no confidence intervals can be provided for model outputs. We are not aware of case study comparisons comparing ORVal estimates with recreational sites with known visitor numbers. In our view ORVal estimates of visit numbers at the Combined Authority level may be accurate to within plus or minus 50%. At the local or site level accuracy will be lower and some estimates may be misleading. Incorporating additional uncertainty associated with valuation we assess confidence as red.

5.2 Benefits we are not able to monetise

This section sets out benefits that we were not able to monetise for example because estimates of the ecosystem service were not available (e.g. timber production).

5.2.1 Timber and wood products

The recommended indicator for this benefit is the stumpage value of timber production.

Stumpage is the price a private firm pays for the right to harvest timber from a given land base – so it takes account of the harvest costs faced by the firm and the profit they expect to make. This is the approach used in ONS (2019a).

The value of the timber provisioning services is based on *stumpage value x physical amount of timber removed*.

Estimates of the value of timber are available but we are not able to estimate the value for the Tees Valley as data on timber production is not currently available at Local Authority level (Section 4.2.1).

Stumpage prices can be sourced from the Forestry Commission Coniferous Standing Sales Price Index in the Timber Price Indices publication (Forest Research, 2018). National data for the stumpage price of timber is not available at the Local Authority level so we recommend that the national value is used.

5.2.2 Water abstraction

The recommended indicator for this is the value of water abstracted for public purposes.

However, although we can estimate a unit value of water abstracted, we are not able to estimate the total value for the Tees Valley as data on the volume of water abstracted is not currently available at Local Authority level.

We can estimate a value per cubic metre using ONS's natural capital accounts (ONS, 2019a). According to the natural capital accounts, 6,697 million cubic metres were abstracted for public water supply in the UK in 2017 with a total value of £2.54 billion. This represents an average value of 38 pence per cubic metre for the whole United Kingdom.

Using this average value, abstraction of 743 million cubic metres for public purposes in the North East (Section 4.2.2) can be valued at ~£282 million/year (0.38 x 743 million).

Alternatively, White et al. (2015) obtained time series data on the volume of water abstractions within English Protected Area boundaries. They estimated resource rent "in a similar way to the ONS accounts" (White et al., 2015, p. 62 in appendix). The five-year average (2010-15) using this approach was lower at 14 pence per cubic metre (2013 prices) so gives a lower value. We recommend this could be used as a sensitivity where abstraction figures are available.

5.2.3 Urban cooling by vegetation

The recommend value for this benefit is the avoided cost due to urban cooling by vegetation.

However, estimates of urban cooling by vegetation at Local Authority level would require specialist input to develop and are therefore outside the scope of this technical report.

ONS (2019a) report that the total annual value of cooling from green and blue space in 2017 was £247.8 million for Great Britain. This analysis draws on work by Kuyer, Dickie, et al. (2018).

This value is based on an assessment of the cooling effect of vegetation and the number of hot days. The value of the cooling effect represents the cost savings from air conditioning and the avoidance of labour productivity loss due to heat.

ONS (2019a, p. 41) reports estimates for 13 'city regions'. Avoided cost for the North East was £350,000 in 2016 and £40,000 in 2017. The North East 'city region' includes County Durham, Northumberland, Newcastle, North & South Tyneside, Gateshead & Sunderland.

Estimates for the TVCA area are not included but may be expected to be lower than the above amounts, given the relative extent of the urban areas and population.

5.2.4 Cultural wellbeing – physical and mental health

Physical and mental health benefits from recreation and access to green and blue space (£/year).

Estimates of physical and mental health benefits at Local Authority level would require specialist input to develop and are outside the scope of this technical report.

According to Defra (2020) the valuation evidence for 'supporting physical health' is "some evidence, but incomplete or uncertain", whilst the evidence for mental health is not yet sufficient to be incorporated into its Enabling a Natural Capital Approach services databook.

Relevant recent work that provides indicative estimates of health benefits or developing methodologies include the following:

Physical health benefits for UK urban areas are included in ONS Urban natural capital accounts (ONS, 2019b), with the health benefits associated with active visits to urban greenspace in 2015 valued at £4.4 billion per year.

ONS (2019a) does not include physical and mental health benefits, beyond those that may be indicated by willingness to pay for recreational visits and housing with access to green/blue space. This avoids double counting, since at least some of these benefits will already have been included in the benefits of recreational visits.

Dickie et al. (2018) estimate the increase in quality of life resulting from increased physical activity associated with recreational visits to greenspace. They note that these welfare gains may double count the welfare value of recreational visits (above) and so do not include them in aggregate values.

Dickie et al. (2018) also estimate health costs per inactive person to be around £650. Total avoided direct and indirect clinical health costs of inactivity are estimated to be nearly £56 million per year in Greater Manchester. Mental health benefits are estimated to be approx. 5% of all health related spending – totalling £264 million per year.

5.2.5 Cultural wellbeing – aesthetic benefits

This benefit can be valued by estimating the increase in property values from living close to publicly accessible green and blue space.

However, estimates of aesthetic benefits at Local Authority level would require specialist input to develop, for example to estimate the number of properties living close to accessible greenspace, and are therefore outside the scope of this technical report.

ONS (2019a) uses the hedonic pricing approach to estimate that “living within 500 metres of publicly accessible green and blue spaces added on average £2,800 to property prices in urban areas”. This value includes both the recreational and aesthetic benefits of living close to greenspace. For the whole of the UK the value is estimated to be £78.0 billion.

5.3 Significance ratings

Based on an exploratory exercise with some local stakeholders, the most significant benefits from natural capital in the Tees Valley were identified as flood regulation, water abstraction, air pollution regulation, carbon sequestration and cultural wellbeing. In addition, natural capital in the Tees Valley was seen as high significance (3) for thriving wildlife but was given an agreed rating of 2 as it was felt that important habitats for wildlife were currently not delivering as effectively as they could if they were in better condition.

It is worth noting that carbon sequestration was given a high significance rating, despite our estimate being of net emissions. This significance rating could therefore be assumed to represent only those habitats that sequester carbon.

Importantly, of the highest significance benefits only air pollution regulation, carbon sequestration and recreational visits could be valued. This shows how partial our valuation is and demonstrates the importance of including significance assessments in natural capital accounts.

5.4 Costs

Natural capital accounts usually look to include the costs to maintain assets. In this study we include all natural capital within the Tees Valley area, rather than just the land owned and managed by Local Authorities. It was therefore too complex to estimate maintenance costs within the constraints of this project.

5.5 Uncertainty

Our confidence levels for the value figures included in the Tees Valley Combined Authority area extended balance sheet are all amber or red. We have not been able to quantify and/or value several important services and benefits. Estimates of non-market benefits are inherently uncertain so these confidence levels are unsurprising. This highlights the importance of including this information to provide a transparent and accurate representation of the information being presented.

More accurate figures could be estimated for some market benefits using organisational data. For example, in Natural England’s NNR Accounts some market benefits were categorised as green as they were based on data available from the Natural England accounts. However, the reliance on national datasets to produce the TVCA area Account as well as inclusion of all natural capital assets within the TVCA area, (rather than only assets owned by a single organisation), meant that more accurate data was not available.

6 Results (Extended balance sheet)

Table 24 sets out the results of all parts of our analysis, including assets, services and benefits, together in the form of an extended balance sheet. The balance sheet is also included in Microsoft Excel format as Appendix G.

Table 24 Tees Valley natural capital – Extended balance sheet

Ecosystem asset

Natural capital asset baseline

Asset Attribute	Indicator	Value
Extent	Total area (ha)	75,000
Hydrology	Ground water quantity status (% good) Water Framework Directive (WFD)	69%
	Hydrological status (% good) WFD	19%
	Bathing water quality (% good)	100%
Nutrient/ Chemical status	Surface water quality status (% good) WFD	37%
Soil/ sediment processes	Mean Estimates of Soil Organic Carbon in Topsoil, 0-15cm depth (tonnes per ha)	52.7
	Soil invertebrate abundance, mean estimates of total abundance in topsoil (0–8cm depth soil core)	40.0
Species Composition		
Vegetation	Nectar plant diversity, mean estimates of number of nectar plant species for bees (per 2×2m plot)	4.2
Cultural	% area of Sites of Special Scientific Interest in favourable condition	51%
	Public rights of way (km/ha)	0.012
	Area of designated historic environment assets (ha)	535
	Scheduled monuments at risk (ha)	148

Ecosystem services

Ecosystem service (common name)	Indicator	Quantity where available
Timber and other materials	Sales of wood and wood products (tonnes/year)	
Fish, marine products & game	Fish and marine products landed (tonnes)	1,500
Livestock	*Number of cattle, sheep and pigs*	*130,000*
Crops	*Cropped area (ha)*	*21,000*
Water supply	Quantity abstracted for public water supply	
Clean water		
Clean air	*Annual mean concentration of $PM_{2.5}$ at AURN network monitors ($\mu g/m^3$)*	*7-10*
Pollution regulation	PM2.5 removed by woodland (tonnes/year)	28
Erosion control		
Flood protection		
Pollination		
Pest and disease control		
Thriving wildlife		
Climate regulation	Carbon sequestration, t CO_2 equiv/yr Emission (arable & horticulture) Sequestration (other habitats)	(~157,000) ~84,000
Cultural - Experiential and physical use	Number of recreational visits (million/year)	25
Cultural appreciation of nature		
Cultural - Scientific and educational use		

Notes:
Gaps are shown as greyed out boxes where data was not available to measure an attribute.
Indicators in *italics* are best available proxies for services. Values in red are negative
Significance ratings based on exploratory exercise conducted with a small group of Tees Valley stakeholders.
Confidence in values: Red is low, Amber is medium, Green is high

Benefits and values

Benefit	Significance (1 small to 3 large)	Indicator	Annual benefit	Asset value	Confidence in the values
Timber, hay and other materials	1	Timber and wood products, stumpage value			
Food	1	Net income from fisheries	£360,000	£11 million	
	1	Resource rent from crop and livestock production	~ £0	~ £0	
Clean and plentiful water	3	Value of water abstraction			
Clean air	3	Health benefits from PM2.5 removal	£8 million	£235 million	
Protection from floods and other hazards	3	Value of flood protection benefits provided by natural capital			
Pollination and pest control	1	Value of pollination and pest and disease control			
Biodiversity	2				
Equable climate	3	Social cost of carbon emission (natural capital)	(£5 million)	(£395 million)	
Cultural wellbeing	3	Social benefit of recreational visits (parks, beaches & paths)	£100 million	£3.0 billion	
	3	Physical and mental health and other benefits			

Total quantified monetary benefits	**£103 million**	**£2.8 billion**
Significance of unquantified monetary benefits	**Very large**	

7 Decision-support case study

Over time natural capital accounting could have a role to play in supporting decision-making. To this end we undertook a case study, summarised below, to explore how the use of natural capital accounting could improve project planning, using net zero carbon as an example.

7.1 Net zero carbon ambitions

Our case study explores the use of natural capital accounting to improve project planning for the Tees Valley Combined Authority goal of achieving net zero carbon in the area by 2040 (TVCA, 2019). We review the literature to identify viable approaches to emissions reduction. Using these approaches we develop a set of actions that will deliver net zero carbon from land use and natural capital[13]. We assess the wider range of benefits that this will deliver and the impact this has on the natural capital account. We outline the benefits of a net zero carbon scenario but do not fully specify all gains and losses and do not appraise the benefits of the scenario against the costs. This study should be viewed as an initial study which lays the foundations for more detailed work in the future.

Achievement of net zero carbon means that net emissions, after accounting for removals, must be reduced to zero (Committee on Climate Change, 2019). Achieving this net-zero target will require deep reductions in emissions, with any remaining sources offset by removals of CO_2 from the atmosphere.

This case study is about the role of natural capital in achieving net zero. This role may involve measures to increase carbon sequestration across several habitats through management, protection, land use change and other measures including tree planting. It may also include measures to reduce current and future emissions from arable and horticultural activities.

It is also important to note that natural capital has an important role in mitigation and adaptation to climate change e.g. natural flood management and cooling by trees (European Commission, 2006). At the same time climate change will have a large impact on natural capital assets (Intergovernmental Panel on Climate Change, 2007); leading to change in the characteristics, quantity and quality of these assets over time.

[13] The TVCA has stated its ambition that *"…the area will achieve a net zero carbon industrial cluster by 2040, providing good jobs with long-term prospects that local people can access*". (TVCA, 2019). However, this case study focuses on applying this ambition to natural capital rather than 'industrial cluster' activities to reduce emissions including waste to energy and carbon capture.

7.2 Baseline emissions

Using BEIS (2019a) estimates of carbon dioxide (CO_2) emissions by Local Authority and incorporating emissions that are not CO_2 (BEIS, 2020) we estimate that total net emissions of all greenhouse gases in the TVCA area were ~ 8.1 million tonnes of CO_2 equivalent in 2017. Current emissions and sequestration by natural capital assets are very small compared to the overall emissions from the TVCA area. Total emissions from arable and horticulture of around 157,000[14] tCO_2e, comprise around 2% of total emissions. Total sequestration by other habitats of around 84,000 tCO_2e comprise around 1% of total emissions, with overall net emissions being around 73,000 tCO_2e (Section 4.1.5). We find that natural capital can contribute to net zero carbon by reducing emissions from agriculture and increasing sequestration by other assets so achieving net zero carbon from natural capital assets by 2040. Natural capital is unlikely to be able to offset a significant proportion of emissions from other sectors by 2040.

7.3 Net zero carbon scenario

We reviewed recent literature on the potential for increased sequestration by natural capital assets to identify a net zero carbon scenario.

The UK Committee on Climate Change (2020) state that "the UK's net-zero target will not be met without changes in how we use our land" and go on to show how "it is possible to reduce land-based emissions of greenhouse gases while contributing to other strategic priorities for land such as food production, climate change adaptation and biodiversity".

The committee conclude that UK emissions from agriculture, land use and peatlands (58 $MtCO_2e$ in 2017) can be reduced by 64% by 2050. We incorporate this assumption into our emissions reduction scenario.

The UK Committee on Climate Change (2020) has identified actions "…such that around one-fifth of agricultural land is released by 2050 for actions that reduce emissions and sequester carbon". These actions include low-carbon farming practices, afforestation and agroforestry, restoration of peat lands and expanded production of bioenergy crops. Assuming even implementation over time, this would require around 13% of agricultural land to be released by 2040.

For the purposes of this case study we explore the effect of converting 10% of agricultural land to forestry/agroforestry over a phased programme from 2020 to 2030 (5% from arable, 5% from improved grassland).

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[14] There is some double counting since agricultural emissions estimates include machinery etc which is included in the CO_2 accounts – but this will have little effect on the broad estimates provided.

Estimates of carbon sequestration from these new woodlands is heavily dependent on a range of assumptions, such as the species planted, rotations and the soil type where new woodlands are planted (Gregg et al., 2021). Based on Morrison et al. (2012), average sequestration rates for sitka spruce plantings for alternative first rotations and assumptions range from 0.8 to 6.3 tCO_2e per year per hectare over the full management cycle. Results for Oak range from 2.4 to 7.5 tCO_2e per year per hectare over the full management cycle (Morrison et al., 2012, Section 5.5 and Appendix 8).

Our assumed emissions estimates for 2040 are based on the results for a forest management cycle for first rotation, managed for thinning and felling (Morrison et al., 2012, Tables 5.13(b) and A8.6(b)). We therefore assume that:

- New planting of Sitka Spruce over the next five years could result in net emissions of 0.2 tCO_{2e} per hectare per year in 2040[15].
- New plantings of Oak could result in sequestration of 5.6 tCO_{2e} per hectare per year in 2040.

In this case study we explore the effects of planting 50% Sitka Spruce and 50% Oak. Based on the data reported in Morrison et al. (2012), we assume this would result in average net sequestration in 2040 of 2.7 tCO_{2e} per hectare per year.

Our net zero scenario therefore involved the following main elements:

- 64% reduction in emissions from arable and horticultural land in the TVCA area, by 2040 (Committee on Climate Change, 2020).
- Conversion of 10% of agricultural land (4,460 ha) to forestry/agroforestry over a phased programme from 2020 to 2030 (5% from arable, 5% from improved grassland) (based on Committee on Climate Change, 2020).
- Average net sequestration in 2040 of 2.7 tCO_2e per hectare per year based on planting of 50% Sitka Spruce and 50% Oak (Morrison et al., 2012).

Table 25, below, shows carbon emissions under the current and emissions reduction scenarios, including the change in total emissions. Current figures are taken from Table 18 (Section 4.1.5).

[15] For our assumed management scenario, we estimate that a new Sitka Spruce planting would be a net carbon emitter in the establishment and initial phases (years 0 to 25), becoming a net sequesterer in the full vigour and mature stages (years 25 to 200). Overall, it would sequester an average of 3.5 tonnes per hectare over the full management cycle. Estimates in 2040 are therefore an under-estimate of the long-term carbon sequestration.

Table 25 Carbon emissions under emissions reduction scenario

		TVCA Area (ha)			C sequestration by habitat (tCO2e/ha/yr)		C sequestration by habitat (tCO2e/yr)	
Broad habitat	LCM habitat class	2020	Change	2040	2020	2040	2020	2040
Woodlands	New planting	-	4,446	4,446	-	2.70	-	12,004
Enclosed farmland	Arable & horticulture	29,128	-2,223	26,905	-5.39	-2.16	-156,999	-58,007
	Improved grassland	15,333	-2,223	13,110	1.55	1.55	23,767	20,321
Other habitats		30,660	0	30,660			60,132	60,132
Total sequestration							-73,100	34,450
Change (2020 to 2040)								107,550

This scenario would enable achievement of net zero carbon from natural capital assets by 2040. Natural capital assets in the TVCA area are currently emitting ~73,000 tCO_2e (net) but under this scenario would instead sequester ~34,000 tCO_2e (net) in 2040. Given the high degree of uncertainty inherent in this estimate we suggest a target scenario such as this one, that results in positive net sequestration is appropriate – to reduce the risk of missing the net zero target if some assumptions are found to be overly optimistic.

The net zero carbon scenario detailed above is ambitious and would require strong leadership and stakeholder buy in. Large scale woodland planting is not easy – this scenario requires planting of more than 400 hectares per year from now until 2030 – whereas only 2,330 hectares was planted in the whole of England in the year to 31 March 2020 (Forest Research, 2020).

7.4 Impact on the Tees Valley natural capital account

Natural capital solutions can deliver benefits across a range of ecosystem services. It is therefore important to assess how the emissions reduction scenario will impact on the delivery of other ecosystem services and benefits.

7.4.1 Changes in asset quantity and quality

The initial emissions reduction scenario would reduce land devoted to agriculture (enclosed farmland) by 4,460 ha allocated equally across improved grassland and arable and horticultural land. At the same time, the area allocated to woodland would double, increasing the overall proportion of woodland to around 6%. Actions taken to reduce emissions from agricultural land by 64% may also improve the condition of natural capital assets. If so, there may be an improving trend in indicators for water quantity and quality, soil organic carbon and soil invertebrate abundance, amongst others.

7.4.2 Changes in Ecosystem services

In Table 26, below, we assess the effect of the net zero carbon scenario on ecosystem services. We include our estimate of greenhouse gas emissions in tonnes. For other services we make an indicative assessment of the likely direction of change using arrows to indicate increases/decreases. In some cases, we have no evidence that the net zero carbon scenario would have a strong effect and indicate this with a 'no change' symbol.

Table 26 Changes in ecosystem services under net zero carbon scenario

Ecosystem service	Indicator	Quantity (2020)	Quantity (2040)
Timber and other materials	Sales of wood and wood products (tonnes/year)		↑
Fish, marine products & game	Fish and marine products landed (tonnes)	1,500	↔
Livestock	*Number of cattle, sheep and pigs*	*130,000*	↓
Crops	*Cropped area (ha)*	*21,000*	↓
Water supply	Quantity abstracted for public water supply		↔
Clean water			↑
Clean air	*Annual mean concentration of $PM_{2.5}$ at AURN network monitors ($\mu g/m^3$)*	*7-10*	↑
Pollution regulation	PM2.5 removed by woodland (tonnes/year)	28	↑
Erosion control			↑
Flood protection			↑
Pollination			↔
Pest and disease control			↔
Thriving wildlife			↑
Climate regulation	Net carbon sequestration, t CO_2 equiv/yr	(73,000)	34,000
Cultural - Experiential and physical use	Number of recreational visits (million/year)	25	↑
Cultural appreciation of nature			
Cultural - Scientific and educational use			

We expect the emissions reduction scenario to result in improvements in many categories of ecosystem services.

- Woodland planting and reduction in emissions from agricultural land would eliminate current net emissions (~73,000 tCO_2e) and enable net sequestration of ~34,000 tonnes in 2040.
- Production of timber and other materials may increase because of new woodland plantings and better management of existing woodlands.
- Increasing the area of woodland is expected to lead to improved water quality (clean water) and better air quality (clean air) because of the mitigating action of vegetation on particulates.
- Improvements are also expected in erosion control (since woodlands tend to reduce erosion) and flood control (since woodland tends to slow run off and reduce flood peaks).
- Larger areas of woodland and management of agricultural land to reduce emissions may also lead to benefits for wildlife (thriving wildlife).
- Woodland planting and reduction in emissions from agricultural land may also lead to improvement in cultural services indicators such as number of recreational visits.

Conversely, with the conversion of some agricultural land to woodland, there would be a reduction in food production.

7.4.3 Changes in benefits

In Table 27, below, we assess the effect of the net zero carbon scenario on benefits and values. We include the new monetary value of greenhouse gas emissions. For other benefits we make an indicative assessment of the likely direction of change.

Table 27 Changes in benefits and values under net zero carbon scenario

Benefit	Significance (1 small to 3 large)	Indicator	Annual benefit (2020)	Annual benefit (2040)
Timber, hay and other materials	1	Timber and wood products, stumpage value		↑
Food	1	Net income from fisheries	£360,000	⇔
	1	Resource rent from crop and livestock production	~ £0	⇔
Clean and plentiful water	3	Value of water abstraction		⇔
Clean air	3	Health benefits from PM2.5 removal	£8 million	↑
Protection from floods and other hazards	3	Value of flood protection benefits provided by natural capital		↑
Pollination and pest control	1	Value of pollination and pest and disease control		⇔
Biodiversity	2			↑
Equable climate	3	Social cost of carbon emission (natural capital)	(£5 million)	£5 million
Cultural wellbeing	3	Social benefit of recreational visits (parks, beaches & paths)	£100 million	↑
	3	Physical and mental health and other benefits		

In considering the benefits and costs of the net zero carbon scenario we note that:

- Moving from the current level of net emissions (~73,000 tCO_2e) to net sequestration of ~34,000 tonnes in 2040 would increase the monetary value of quantified benefits by ~£10m per year by 2040. These benefits increase substantially over time as the cost of carbon emissions increases, such that, assuming net sequestration remains at 34,000 tonnes beyond 2040, the net present value of this emissions reduction scenario (relative to emissions continuing at current levels) over the next 100 years is estimated to be over £500 million[16].
- Woodland planting and improved woodland management may lead to a sustainable increase in the value of timber and wood products harvested. Appropriate harvesting of wood products may assist achievement of net zero carbon – for example by incorporating timber into long lived structures.
- The resource rent from crop and livestock production is currently estimated to be close to zero or negative (Section 5.1.2). The effect on resource rent of emissions reduction and a reduced area devoted to crop and livestock farming is unknown. In the absence of a more detailed assessment we assume no change in resource rent from crop and livestock production (although as noted above, there is a loss in food production).
- Increasing the area of woodland is expected to lead to better air quality (clean air) because of the mitigating action of vegetation on particulates. We do not attempt to estimate the size of this benefit.
- Woodland planting and reduction in emissions from agricultural land may increase benefits from recreation and other physical and mental health benefits. This is more likely if the additional plantings are located close to population centres and are specifically designed to encourage recreational activity. In this case the increase in the value of cultural benefits could be very large.

It is important to note that we have not assessed the cost of planting and maintaining an additional 4,446 hectares of woodland. A full appraisal of the net zero carbon scenario, or other potential scenarios, would benefit from a more detailed consideration of the change in benefits as well as the associated costs. However, this provides an indicative demonstration of the multiple benefits that could be delivered through a natural capital net zero carbon policy.

[16] Detailed calculations provided in **Error! Reference source not found.** (Microsoft Excel Spreadsheet).

8 Discussion

8.1 Extended natural capital accounts

Natural England has developed an approach to accounts that seeks to address problems of uncertainty and partial valuation. Presenting information on asset extent and quality alongside ecosystem services, benefits and values, is important to support decision making. In this case, we used asset quality indicators from the Tees Natural Capital Atlas that best describes attributes of our natural capital assets and their ability to continue to provide benefits into the future. This approach acts as a baseline which future accounts can be measured against. It also provides far greater information on the system as a whole.

8.2 Difficulty in linking the logic chain

The conceptual framework describes the link between the natural environment and the provision of ecosystem services and benefits. In reality, this relationship is a complex web of interactions and influences that we only partially understand. The ideal for a natural capital account is to value all the benefits and link them back to services and to the asset state. At present this ideal is unachievable. For some benefits we have ecological information, but not enough to quantify the benefit. Water quality is an example. For others we can quantify a benefit, but we don't know how it relates to asset quality. For example, we can estimate recreational visitor numbers and value these, but these are based on a national econometric tool that, whilst it “captures many important features that influence the value and visitation to greenspace it is not able to account for each park’s unique characteristics” (Day and Smith, 2018). It does not therefore account for the quality of greenspace in the Tees Valley. Our estimates of carbon emissions (and associated value) also only vary by asset type, not quality.

Our simplified logic chain only partly captures the complexity of the real system. There is a lot that we do not understand and where we have some understanding it is often at a low level of certainty. Natural capital accounting sets a high-bar for quantified and proven evidence. There are alternative approaches designed for complex systems, such as Bayesian Belief Networks. These may have a complementary role in natural capital accounting or it may possible to develop hybrid approaches.

8.3 Asset value of natural capital in the Tees Valley

Overall, we estimate the monetary value of quantifiable benefits from natural capital in the Tees Valley to be in excess of £100 million per year with a natural capital asset value of almost £3 billion. There are benefits of ‘very large’ significance that we have not been able to value in monetary terms and suggest that, based on the level of significance placed on these non-monetised benefits, these are likely greater than the quantified values.

The majority of benefits which we could value were from recreation, which were estimated as being of the order of £100 million per year. The next most significant were the health benefits associated with improved air quality, at about £8 million per year. We also estimate small benefits associated with fisheries, crops and livestock.

Additionally, we quantify the contribution natural capital assets make to sequestering or emitting carbon. Focussing only on those habitats that sequester carbon, we estimate a benefit of about £5.7 million. However, these benefits are outweighed by the emissions from arable and horticultural habitats. Overall, we estimate that current net carbon emissions from natural capital assets in the Tees Valley have an annual social cost of around £5 million.

Benefits that we cannot value in monetary terms provide large additional benefits and some are highly significant. Those identified as most significant were water abstraction, flood protection, biodiversity and, physical and mental health. Other non-monetised benefits include timber, pollination services and other cultural benefits that people gain from nature, such as scientific and educational opportunities and cultural appreciation. The £103 million per year figure represents only those services that can be valued in money terms, not those that are most important. It is therefore a significant under-estimate of the true value of natural capital across the Tees Valley.

The confidence rating for the quantified benefits are all amber or red. This means we have only moderate or low confidence in the values we present. Collecting bespoke local data would improve our confidence in some of the estimates, particularly market benefits, but uncertainty will remain elsewhere due to the nature of how non-market benefits are estimated.

To produce an asset value we need to estimate the stream of benefits in future years. We have assumed that they will remain the same as this year, although the social cost of carbon emissions will increase into the future because carbon values increase in future years[17] (as explained in Section 5.1.4). This leads to an asset value calculation of almost £3 billion. There are three important caveats to the asset value. First, the asset value calculation is as partial as the yearly flow calculation. Second, it's a gross value, without costs of maintenance netted off. Third, we do not know how the quantified benefits will evolve in future.

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[17] The unit cost of carbon emissions represents the cost of other measures to remove the equivalent amount of carbon at that point in time. It is therefore scheduled to rise sharply over the next 50 years. If emissions remain at current levels the annual cost of these emissions would reach £26 million in 2073.

8.4 Understanding the state of the assets themselves

Without our natural capital assets, there would be no ecosystem goods and services, and associated benefits and values to society and the economy. It is in our interest to understand what state our natural capital assets are in and how they are changing over time. This report has attempted to set a meaningful baseline in terms of asset extent and quality, against which we can measure change in the future.

By mapping indicators within a region using a national scale, the Natural Capital Atlases also provide context on the state of assets relative to the national picture. This helps to show whether assets are currently in a good state. In this account we provide further context by comparing the Tees Valley indicators with the national average. However, this is a simple comparison that does not consider the characteristics of the Tees Valley relative to other areas. The extensive set of data published to accompany the Natural Capital Atlases provides the potential to further explore benchmarking of areas.

One of the biggest constraints to mapping natural capital in the Atlases was data availability. We struggled to find datasets of suitable resolution, that are repeated and describe the asset attributes that we are interested in and that are available consistently across England. We have had to use some datasets which may not be repeated. We were also restricted to using data sources which were either available under an Open Government Licence (OGL) or where data providers were happy for the derived products to be published under an OGL. This limited the data selection process further. The lack of relevant data is a significant problem for work on natural capital in general and there is no quick fix. Whilst tools such as earth observation may help us in the future, we still need to maintain and increase investment in datasets that tells us information about the state of our natural environment at scales that make sense locally as well as nationally. Defra is funding the Natural Capital and Ecosystem Assessment pilot which is developing better ways to collect and assess data on our natural capital assets and ecosystems. Lusardi et al. (2018) highlights the gaps in our data in further detail.

The intervals between repeat surveys for the ecological data in this report suggests that repetition annually of this account would not be appropriate as the ecological data is not collected on an annual basis. For example, soil quality indicators have been estimated using Natural England and CEH's Mapping Natural Capital project (CEH and Natural England, 2016). This data has not been updated since 2012.

This lack of information means that some aspects of quality have not been included in Natural Capital Atlases and, therefore, these accounts. Consideration of landscape for example has not been possible. Further work is required to find datasets to capture these attributes in future accounts.

To encourage the inclusion of asset extent and quality information alongside ecosystem services, benefits and values in decision making, we summarised the results on one page (Section 6). We could not include all the information on asset quality in this summary but have chosen datasets across the six quality attributes. Focussing on the summary so tightly risks readers ignoring the wider data, but we felt that presenting asset data alongside valuation data was essential in this work. It is important that this summary is therefore considered alongside other indicators in the Natural Capital Atlas.

8.5 Improving City-scale assessments in future

This report is our first attempt at a natural capital account at County or City Region level. Our approach was exploratory, with the objective of using Natural Capital Atlas indicators and supplementing this only with publicly available data and methodologies that could be used and replicated in other areas. This approach has shown the difficulty of producing an Account in this way, with a limited number of relevant, spatially disaggregated, national datasets and models for services and benefits. There are huge opportunities for further data collection and modelling to fill gaps and improve the Tees Valley Account, such as around timber production, flood mitigation and water supply. A further improvement would be to incorporate costs of maintaining natural capital and how these are distributed across different sectors.

However, the complexity of the environment means that natural capital accounts will always be partial. This is why the innovations we have developed, such as the presentation of asset quality alongside monetary values in the final balance sheet, are crucial in presenting a transparent picture to decision-makers.

The Account provides evidence on total benefits across the Tees Valley. It does not assess how they vary within the region. Using the Account alongside the Tees Natural Capital Atlas, provides a representation of the distribution and condition of natural capital assets across the area. Providing information on how benefits are distributed across the Tees Valley, such as by Local Authority, would provide useful detail to further support decision-makers.

8.6 Natural capital accounting alone does not provide appropriate headline targets for managing natural capital

It wouldn't be appropriate to manage natural capital by maximising the quantified asset value. This would prioritise recreation, air quality and carbon sequestration above all else. Recreation is an important benefit of natural capital, particularly close to urban areas. But there are tensions between recreation and thriving wildlife. Maximising recreation at the cost of thriving wildlife would be inappropriate. Replacing agricultural land with woodlands would deliver carbon benefits but this could be at the expense of other goods and services, as explored further in the case study (Section 7). So, focussing on the quantified value and investment ratio would not be appropriate.

8.7 Even so, the detail about benefits is helpful

Recognising the value of natural capital across a broad range of benefits through the lens of ecosystem services is really worthwhile to highlight the full suite of services and benefits they provide. The Economics of Ecosystems and Biodiversity report (TEEB, 2010) identified that often recognising value was sufficient to inform decision making and this study supports that. Similarly, previous work by Natural England (Clark, 2017) which took a bottom up approach to Corporate Natural Capital Accounting found that NNR managers found the approach to thinking about their sites in broader terms helpful, but that the final accounts were too partial to be particularly useful.

Assessment of the significance of ecosystem services and benefits was assessed by a small group of Tees Valley stakeholders. This worked well to engage these stakeholders and the small number of participants helped when agreeing consensus ratings. However, a more inclusive approach to determining significance of the services and benefits could be followed to increase the number of stakeholders involved in the creation of the account. This could also be useful to engage relevant stakeholders who may have useful data that could improve the account.

Benefit figures provide a way of engaging those unfamiliar with the benefits of natural capital. The detailed benefit figures can also form part of a case for further investment in these areas.

The approach to understanding asset extent and quality, in line with Lusardi et al. (2018), also extends ecological interest beyond biodiversity to aspects of naturally functioning ecosystems, their associated processes, and cultural considerations. This gives a broader perspective of the sustainability and resilience of natural capital.

9 Conclusion

Natural capital in the Tees Valley offers significant benefits to society. The most significant benefits are varied, including recreation opportunities, physical and mental health benefits, improved air quality, thriving wildlife, water supply and flood mitigation. Benefits from climate regulation, provision of goods, health and broad cultural well-being are also significant. Beyond this there is a long list of ecosystem services where natural capital assets make a modest contribution. We were able to put an economic value on only a small proportion of the benefits, but even this partial valuation helps to illustrate the importance of natural capital to people in the Tees Valley.

This innovative approach to natural capital accounts provides a baseline assessment of the quantity and quality of natural capital assets, the services and benefits provided, and their value all reported alongside each other in an extended balance sheet. This provides comprehensive, accessible information that is available for better decision-making and avoids the problems of partial natural capital accounts.

Our asset values are based on the assumption that the benefits from natural capital will stay the same. To ensure that the benefits do stay the same, or increase, we need to understand the ecology. We also need to understand how this delivers benefits. This is best done at site level, but it's also useful to understand it strategically. Our assessment in this report is a first pass at this and a baseline for comparison.

Leaving the environment in a better state for future generations will require meaningfully linking financial decisions with environmental assets and benefits. This study is a contribution to this long-term task. We commend this approach to all organisations which are committed to managing their environmental assets to deliver public benefit over the long-term.

List of tables

List of figures

Appendix A. Tees Valley Natural Capital Atlas

Attached as separate document.

Appendix B. Tees Valley Natural Capital Atlas attribute tables and asset quality indicator calculations

Attached as separate Microsoft Excel spreadsheet

Attribute tables key

Definitions of the columns in the attribute tables are available in Lear et al. (2020) Natural Capital Atlas: County scale, GIS User Guidance, pages 11 to 12. Available at http://publications.naturalengland.org.uk/publication/6672365834731520

Note: for the calculations based on the Tees Valley Natural Capital Atlas we used an alternative version of Atlas data to that which is available in the shapefiles published alongside the City/County Natural Capital Atlases (Section 2.1.3). This was because for some indicators, the data was not in a format that could be used to estimate asset quality indicators. For example, for indicators where we used WFD data this account reports the percentage of length of river classified as good. However, the final approach chosen in the county/city scale natural capital atlases was to present the raw WFD data to show the variation of quality across the area.

Table 28 provides a list of the columns in the Tees Valley Attribute table that are different to the published shapefiles and the equivalent attribute table headings that are used in the City/County Natural Capital Atlases.

Table 28 Attribute Table Headings that differ between the Tees Valley Attribute Tables and City/County scale Natural Capital Atlases

Tees Valley Attribute Table Heading (Appendix B)	City/County Natural Capital Atlas Attribute Table Heading (Lear et al, 2020)
NatAquiferFunc	GoodStatus
NatFlowRegime	REG_CLASS
LackPhysModRivers	SWMIPhysMod
RiverCont	NA
NutriWBs	PHO_CLASS
VegCover	*Not included (data used to estimate VegCoverPer)*
All_FavSSSI	CONDITION
All_NaturalWater	ECO_CLASS

Additionally, the Tees Valley Atlas and associated attribute tables were specifically produced for this project as the Tees Valley did not originally have its own Natural Capital Atlas – instead it was combined with the North East Combined Authority for presentational purposes.

Appendix C. Additional resources

Table 29 sets out resources identified during development of the account that provide additional information relevant to the Tees Valley.

Table 29 Additional Tees Valley resources

Publication, tool or data source	Notes	Source or link
Tees Lowland National Character Area Profile 23	This NCAP profile covers much of the same area as TVCA area	NCA Profile: 23 Tees Lowlands - NE439
North York Moors National Character Area Profile 25	Part of this NCAP profile is relevant to eastern part of Redcar and Cleveland	
Redcar and Cleveland air quality report	Tees Valley has three PM2.5 monitors as part of the national AURN network, Breckon Hill within Middlesbrough, Eaglescliffe and A1035 Nelson Terrace both located within Stockton-on-Tees. The annual means measured at these monitoring locations range from 7 to 10 µg.m3, data has been obtained from colleagues at both councils and from the Defra AURN website, https://uk-air.defra.gov.uk/data/exceedence	Redcar & Cleveland Borough Council (2019)
Ecosystem Service Interactions – Spatial Interactive Tool	A web-based decision support tool to visualise impacts of landscape management on ecosystem services Two versions of ESI-SIT have been developed to date, one for the Humberhead Levels Nature Improvement Area, and one for the Tees Valley.	http://www.esi-sit.com/

Tees data set **CaBA (Catchment Based Approach)**	Tees data-set developed by Tees Rivers Trust based on open source data.	
Wildlife sites and opportunity maps (GIS layers)		www.teesvalleynaturepartnership.org.uk Network opportunity maps Biodiversity Opportunity Area Pilot
Tees Valley, local environment and economic development. Report of the Level 1 Workshop (2017)	This report is a note of a Level 1 workshop which used the Local Environment and Economic Development (LEED) process	Murtagh (2017)

Appendix D. Instructions for exercise with local stakeholders to assess significance

Assessment of the significance of ecosystem services and benefits

Please use your knowledge of the Tees Valley Combined authority area to assess the significance of ecosystem services and benefits in the area where: – ***any ecosystem service/benefit that is valued by local people or that provides benefits to local people and other stakeholders is considered to be significant.***

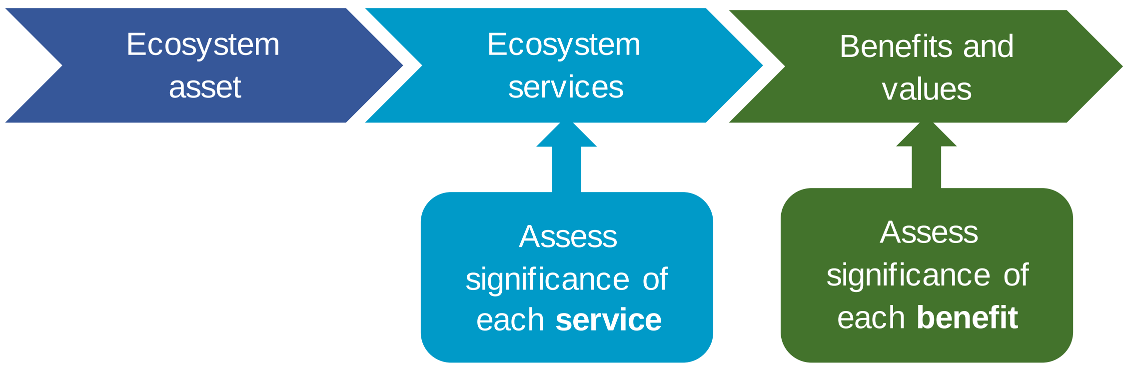
Please base your assessment on a scale with four levels, each ecosystem service/benefit being assigned a score of 0 (none), 1 (low), 2 (medium) or 3 (high).

Significance levels

Significance		**The ecosystem service provides social benefits that are ….**
0	None	Very low/minor or absent
1	Low	*Relatively low* across the selected area
2	Medium	*'Medium'* across the selected area
3	High	*High* across the selected area

Assessment of significance allows us to present a more complete picture to decision makers by focusing on important services whether or not they can be quantified or valued. It reduces the risk of people focussing on things that we can value in £ while paying less attention to very important aspects that we cannot value.

The logic chain diagram below shows where we assess significance in the flow from ecosystem assets to ecosystem services to benefits and values. In this exercise we assess significance of both ecosystem services and of benefits.



Outline of initial exercise to assess social significance

- Convenor explains the purpose of the exercise, including the need to rank ecosystem services and benefits into four significance categories
- Participants/stakeholders break into groups
  - Each group is provided with instructions and two A4 sheet – divided into 4 columns (No significance to High significance)
- Groups to discuss the significance of each service/benefit
  - e.g. How significant (to local people) is the **ecosystem service** “timber and other materials”?
  - How significant (to local people) are the net **benefits** from crop and livestock production?
- Each group attempts to reach an agreed assessment of significance and fill in the sheets for ecosystem services and benefits
- Convenor identifies differences and brings these to the whole group to discuss and try to reach consensus.

Ecosystem services – Assess the social significance by selecting one score category for each ecosystem service

Ecosystem Service	Description	0 None/minor Very low/minor or absent	1 Low Relatively low across the selected area	2 Medium Medium' across the selected area	3 High High across the selected area
Timber and other materials	Materials e.g. hay, grass for fodder, timber				
Fish and marine products	Game, freshwater fish, marine fish and shellfish. Includes commercial and subsistence fishing and hunting for food				
Aquaculture	Products from aquaculture e.g. fish, shellfish & seaweed for food, fertiliser, angling bait, medicines				
Livestock	Products from animals e.g. meat, dairy products, honey				
Crops	Food from crops e.g. cereals, vegetables, fruit				
Water supply	Plentiful water e.g. water for drinking, domestic use, irrigation, livestock, industrial use including cooling, wildlife				
Water quality	Clean water, also underpinning e.g. water supply, sustainable ecosystems, cultural services, health benefits				
Air quality	Clean air, also underpinning health benefits and sustainable ecosystems				
Erosion control	Erosion control e.g. soil/land retention, lack of transport disruption, protection of housing, business and infrastructure				
Flood protection	Reduced flood risk e.g. reduced health & safety risk, protection of housing, businesses & infrastructure, lack of transport disruption				
Pollination	Pollination underpinning cultivated crops dependent on insect pollination e.g. field beans, apples, plums				
Pest and disease control	Natural control of agricultural pest species and diseases				
Thriving wildlife	Biodiversity, of itself, and underpinning all services e.g. recreation, tourism, food, flood protection, climate regulation				
Climate regulation	Equable climate e.g. reduced risk of drought, flood & extreme weather events, reduced flood risk				
Other regulating services (pollution removal, noise)	Health benefits and reduced impacts on educational & work performance				
Cultural Services (the 'non-material' services people obtain from ecosystems)					
Experiential and physical use	Cultural wellbeing. This includes: Capabilities e.g. knowledge, health, dexterity, judgement				
Scientific and educational use	Experiences e.g. tranquility, inspiration, escape, discovery				
Cultural appreciation of nature	belonging, sense of place, rootedness, spirituality, sense of history. Non-use values: existence, bequest, altruistic, option value				

Benefits – Assess the social significance by selecting one score category for each benefit

Benefit	Indicator (provides an indication of benefits, may not be comprehensive)	0	1	2	3
		None/minor	Low	Medium	High
		Very low/minor or absent	Relatively low across the selected area	Medium' across the selected area	High across the selected area
Timber, hay and other materials	Net value of timber and wood production				
Food	Net income from fisheries and aquaculture				
	Net income from crop and livestock production				
Clean and plentiful water	Benefits from abstraction of clean water				
Clean air	Health benefits from PM2.5 removal				
Protection from floods and other hazards	Value of flood protection benefits provided by natural capital				
Pollination and pest control	Value of pollination and pest and disease control				
Biodiversity	Benefit of biodiversity				
Equable climate	Benefits of less climate change e.g. lower summer temperatures and reduce risk of extreme weather events etc				
Cultural wellbeing (the 'non-material' benefits people obtain from ecosystems)	Social benefit of recreational visits (parks, beaches & paths)				
	Physical and mental health benefits from nature				
	Other benefits from 'nature' e.g. belonging, sense of place & history, non-use values etc				

Appendix E. Further methodology detail on tools

This appendix provides additional detail on how to use the tools we have used in this natural capital account.

Outdoor Recreation Valuation Tool (ORVal)

The Outdoor Recreation Valuation Tool (ORVal) has been used to provide estimates of recreation visits and the welfare value of these.

In order to calculate estimates for a local authority, or multiple local authorities:

Step 1 – Select “local authority” from the menu on the left hand side.

Step 2 – Zoom in to see local authority boundaries.

Step 3 – Click within the relevant local authority boundaries. Multiple authorities can be selected by holding the shift key down and clicking to select.

Step 4 – Click on the recreation icon to obtain estimates of the number of recreational visits in the defined area.

Results are disaggregated by type of greenspace and socio-economic groups.

A technical report detailing the basis for the model estimates is available by clicking on the parallel bars at the top left-hand side of the screen.

Natural Environmental Valuation Online (NEVO)

The NEVO tool has been used to provide an additional estimate for agricultural greenhouse gas emissions to provide a sensitivity check against our estimates based on RSPB, 2017.

To estimate agricultural GHG emissions follow these steps:

Step 1 – Select “local authority” from the menu on the left hand side.

Step 2 – Zoom in to see local authority boundaries.

Step 3 – Click within the relevant local authority boundaries. Multiple authorities can be selected by holding the shift key down and clicking to select.

Step 4 – Click on the CO_2 icon to obtain estimates of carbon emission from agriculture.

Pollution Removal by Vegetation

The pollution removal by vegetation tool has been used to estimate the amount of PM2.5 removed by woodlands.

To estimate the amount of PM2.5 removed by woodland and the asset value of this removal follow these steps:

Step 1 – Select “Local Authorities” from the ‘Choose your Map’ list below the map.

Step 2 – Zoom in to see local authority boundaries.

Step 3 – Click within the relevant local authority boundary. Multiple authorities cannot be selected so repeat for other local authorities.

Appendix F. Carbon prices calculations

Attached as separate Microsoft Excel spreadsheet.

Appendix G. Extended balance sheet

Attached as separate Microsoft Excel spreadsheet.

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Datasets

Dataset sources for figures in main report

The following datasets were used to derive maps included in this report. This includes maps taken from the Tees Valley Natural Capital Atlas. Figure numbers refer to the figures in this Account that have used the dataset.

Centre for Ecology & Hydrology (CEH)

- Land Cover Map 2015 (Figure 2 & Figure 6)

  LCM2015 © NERC (CEH) 2011. Contains Ordnance Survey data © Crown Copyright 2007.

  Rowland, C.S.; Morton, R.D.; Carrasco, L.; McShane, G.; O'Neil, A.W.; Wood, C.M. (2017) Land Cover Map 2015 (25m raster, GB). NERC Environmental Information Data Centre. https://doi.org/10.5285/bb15e200-9349-403c-bda9-b430093807c7

Environment Agency

The following datasets were used in this report: © Environment Agency and/or database right

- WFD Water Body Water Status (Figure 9 & Figure 10)
- WFD River Waterbodies Cycle 2 (Figure 9 & Figure 10)
- WFD Groundwater Bodies Cycle 2 (Figure 8)

Historic England

The following datasets were used in this atlas: © Historic England [2020]. Contains Ordnance Survey data © Crown copyright and database right [2020]

- Scheduled Monuments (Figure 16)
- World Heritage Sites (Figure 16)
- Registered Battlefields (Figure 16)
- Registered Parks and Gardens (Figure 16)

Natural England

The following datasets were used in this atlas: © Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right [2020]

- SSSI Units (Figure 14)

Natural England & Centre for Ecology & Hydrology (CEH)

- Natural Capital Maps (Figure 11, Figure 12 & Figure 13)

Public Rights of Way Data – Multiple Sources

The rights of way data is derived from multiple sources, directed from the rowmaps website: www.rowmaps.com

All datasets used have open licenses (terms equivalent to OS Opendata License or Open Government License). A full list of Local Authorities that produced data that was used to map rights of way in England is included on page 83 of the Tees Valley Natural Capital Atlas (Figure 15).

Natural Capital Atlas and Attribute tables dataset sources

Full details of the sources of data, copyrights and references used in the Tees Valley Natural Capital Atlas, including the attribute tables (Appendices A and B) are provided on pages 82 to 83 of the Tees Valley Natural Capital Atlas (Appendix A).

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

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